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PILOT PLANT SCALE EVALUATION OF BENEFICIATION POTENTIAL OF DONKIN-MORIEN COAL, N.S.

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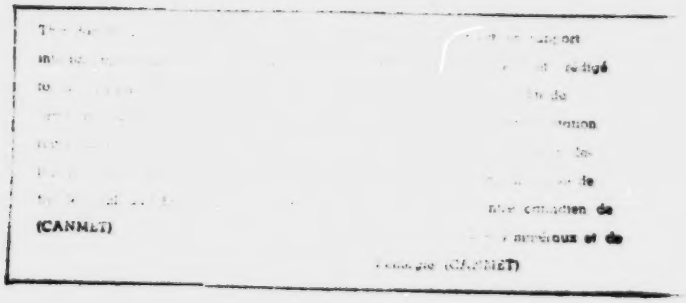

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by

M.W. Mikhail*, O.E. Humeniuk**, A.I.A. Salama***, and I.S. Parsons****

ABSTRACT

As part of a program for evaluation of the beneficiation potential of eastern Canadian coals, Donkin-Morien coal was selected for pilot plant scale evaluation. A bulk sample (74t) was made available for testing at the Coal Research Laboratory facilities at Devon, Alberta. The objective of the study was to determine the limitation and potential of reducing the sulphur content in relation to mass and thermal recoveries. Two flowsheet options were selected to achieve three objectives a) Maximum thermal recovery at limited sulphur removal b) lower sulphur in clean coal to 2% or less, and c) maximum sulphur removal at acceptable mass recovery. Three clean coal samples (approximately 5t each) with different ash and sulphur levels based on the above objectives were made available for testing at the Canadian Combustion Research Laboratory in Ottawa.

Donkin-Morien coal is relatively low in ash (8.24%) but high in sulphur (3.40%) of which 55.3% (of the total sulphur) is pyritic. Moderate ash and limited sulphur liberation were observed when the raw coal was reduced in top size from 50 to 10 mm by crushing. The coal is relatively hard; however, it is expected to generate 19.5% by mass of minus 0.6 mm due to degradation during mining, handling and processing. Washability data indicated that the coal is amenable to significant sulphur removal (50-65%) by density separation at low cutpoints. Laboratory characterization

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also indicated that the coal is easy to float with conventional reagents resulting in more than 45% sulphur removals in the clean coal. Pilot plant runs produced clean coal products with sulphur removals of 33.9 to 65.1% at thermal recoveries of 95.6 and 64% respectively. The performance of the heavy medium cyclone proved its capability to achieve very low cutpoints (1.28-1.33 dp) with efficient separation. However the Batac jig and Water-Only Tricone cyclone performance were below what might be expected partly due to the low ash content of the feed. The pilot plant flotation performed similar to the bench scale tests i.e. showed good results. The water recovery circuit produced clarified water for recirculation at minimum addition of flocculants with no change in the water pH due to sulphur leaching.

Results indicate that Donkin-Morien Coal is amenable to limited sulphur liberation by crushing. However, this advantage may be offset by less efficient separation of finer particle sizes. As a result, it is recommended that the raw coal not be crushed finer than 50 mm top size. The heavy medium cyclone system is the most suitable means to remove 50 to 65% of the sulphur and give a clean coarse coal with 1.3-1.9% ash and 1.6-1.9% sulphur. An option that should be considered is a three-product separation to maximize both sulphur removal and thermal recovery. This option would include a two-stage system for coarse cleaning to produce a premium product (1.6-1.9% sulphur) and a secondary product relatively high in ash and sulphur. The fines would be treated by a combination of a water-only system (cyclones or spirals) and froth flotation.

ÉVALUATION À L'ÉCHELLE-PILOTE DU POTENTIEL DU PROCÉDÉ DE VALORISATION DU CHARBON PROVENANT DE LA MINE DONKIN-MORIEN, N.-É.

par

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RÉSUMÉ

Dans le cadre du programme portant sur l'évaluation du potentiel du procédé de valorisation des charbons de l'Est canadien, le charbon Donkin-Morien a fait l'objet d'un contrôle à l'échelle-pilote. Un échantillon en vrac (74t) a été mis à la disposition des chercheurs, à des fins d'essais, au Laboratoire de recherche sur le charbon, à Devon, en Alberta. L'étude visait à déterminer les limites et le potentiel du procédé utilisé pour éliminer le soufre du charbon en fonction des récupérations massique et thermique. On a choisi deux schémas de fonctionnement en vue de réaliser trois objectifs, à savoir, a) récupération thermique maximale de pair avec une élimination limitée du soufre b) réduction de 2 % ou moins de la teneur en soufre du charbon propre, et c) élimination maximale du soufre et taux de récupération massique satisfaisant. Trois échantillons de charbon propre (d'environ 5t chacun), ayant des teneurs en cendre et en soufre différentes, ont été utilisés pour les essais au Laboratoire de recherche sur la combustion, à Ottawa, en vue de réaliser les objectifs susmentionnés.

Le charbon Donkin-Morien a une teneur en cendres relativement faible (8,24 %) mais une teneur en soufre élevée (3,40 %), dont 55,3 % (du soufre total) est pyriteux. En réduisant la granulométrie du charbon non lavé de 50 à 10 mm par le broyage, une libération modérée de la cendre et un dégagement limité du soufre se sont produits. Le charbon est relativement dur; toutefois on s'attend à ce qu'il produise, d'après son volume massique, 19,5 % de charbons d'une granulométrie de moins 0,6 mm en raison de la décomposition qui

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survient pendant l'extraction, la manutention et le traitement. Les données sur la lavabilité de ce charbon indiquent qu'il est sujet à une élimination de soufre importante (50-65 %) par la séparation de la densité à des points de fractionnement très bas. La caractérisation en laboratoire a également démontré que le charbon flotte aisément au moyen des réactifs classiques, ce qui permet d'éliminer plus de 45 % du soufre contenu dans le charbon propre. Les essais à l'échelle-pilote on permis de réaliser un taux d'élimination du soufre variant de 33,9 % à 65,1 % à des taux de récupération thermique de 95,6 et 64 % , respectivement et d'obtenir un produit propre. La performance du cyclone à milieu dense a démontré que cet appareil peut atteindre des points de fractionnement très bas (1,28-1,33 dp) tout en effectuant la séparation de façon efficace. Toutefois, on s'attendait à une meilleure performance du crible Batac et de l'hydrocyclône Tricone en raison de la faible teneur en cendres de la charge d'alimentation. La flottation à l'échelle pilote de même que les essais ont donné des résultats satisfaisants. Pour la recirculation, le circuit de récupération a produit une eau clarifiée à laquelle n'avait été ajoutée qu'une quantité minimale d'agents floculants et dont le pH n'a pas été altéré par la lixiviation du soufre.

Les résultats démontrent que le broyage permet de libérer le soufre contenu dans le charbon Donkin-Morien. Cependant, cet avantage peut être minimisé en raison de la séparation moins efficace des particules de plus petites dimensions. Par conséquent, on recommande d'éviter de broyer le charbon brut à une granulométrie de moins de 50 mm. Le cyclone à milieu dense est celui qui convient le mieux pour éliminer de 50 à 65 % du soufre et produire un charbon grossier propre dont la teneur en cendre varie de 1,3 à 1,9 % et la teneur en soufre, de 1,6 à 1,9 % . Une autre alternative serait de séparer le charbon de façon à obtenir trois produits afin d'optimiser l'élimination du soufre et la récupération thermique. Cette méthode pourrait comprendre un système à deux étages pour le nettoyage du charbon grossier en vue de produire un produit de qualité (1,6 à 1,9 % de soufre) et un produit secondaire dont le contenu en cendres et en soufre serait relativement élevé. On pourrait traiter les fines en combinant un système à eau seulement (cyclones et spirales) à la flottation par mousse.

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INTRODUCTION

A program for evaluation of the beneficiation potential of eastern Canadian coals was initiated by the Department of Energy, Mines and Resources in 1984. The program involved several tasks including data bank, characterization of different coals, review of existing coal preparation technology and assessment of the technical, economic and social benefits of utilizing beneficiated coal for thermal power generation. Based on these requirements specific coals were selected for extensive testing in a pilot plant program. These tests were carried out in multi-circuit pilot plant facilities at the Canmet Coal Research Laboratory, Devon, Alberta. The pilot plant work is intended to determine the optimum beneficiation processes for eastern Canadian coals and produce clean coal samples for combustion testing and characterization. A complete economic analysis of results from different tasks along with recommendations for action are the final tasks of the program (see Appendix A).

The committee on Atlantic Coal selected Donkin-Morien coal for testing in the pilot plant program based on tasks 1, 2 and 3 (Appendix A). A bulk sample of 74 tonnes was shipped to the Devon Coal Research Laboratory.

Due to a shortage of manpower at CRL, a contract was awarded to the Coal Mining Research Company to assist in the testing program. This involved supplying manpower to help in sampling, sample preparation, handling of raw coal and test products, quality control and characterization analyses (Appendix B). Also, the contract involved an independent study on drying characteristics of three maritime coals.

The bulk sample (74 t) was received at Devon in early April 1985. The pilot plant testing program started in May 1985 and was completed by October 1985. The clean coal samples were shipped (October 1985) to the Canadian Combustion Research Laboratory at Bells Corners near Ottawa for pilot scale combustion testing and characterization.

OBJECTIVES

Laboratory characterization and pilot plant testing objectives were:

1. Determine coal characteristics that are related to the benefication potential of Donkin-Morien coal, e.g. size degradation and distribution, washability, structure and surface properties in relation to flotation and flocculation.

2. Wash the raw coal at a high cutpoint to maximize mass and thermal recoveries and reduce sulphur content by 30% or more at 90-95% thermal recovery by using water-only systems for the plus 0.15 mm and froth flotation for the minus 0.15 mm.

3. Clean the raw coal at a low cutpoint to achieve 50% or more sulphur reduction and produce a high quality clean coal (2% ash). The pilot plan circuit will include heavy medium cyclone, water-only Tricone cyclones and froth flotation.

4. Clean the raw coal at a cutpoint less than 1.30 cutpoint to maximize sulphur reduction using the same circuit as in 3 above on the understanding that the system would be a two stage heavy medium cyclone (HMC). The CRL pilot plant includes only a single stage; the second stage results will be calculated using a HMC model. Alternatively, HMC product may be cleaned in the Batac jig at a cutpoint of 1.70 or less.

5. Produce 5 tonnes of clean coal from each test of the above three flowsheet options for combustion testing at the Combustion Research Laboratory of the Energy Research Laboratories in Ottawa.

6. Relate pilot plant results to a scaled-up commercial operation, considering quality of products, size and coal characteristics in general.

COAL CHARACTERIZATION

The Donkin-Morien Coal mine is located at Cape Perce, near Glace Bay, Nova Scotia and is being developed by the Cape Breton Development Corporation (CBDC). The main coal reserves are in the Harbour seam and recoverable reserves (measured and indicated) are estimated to be 166 million tonnes (1). A bulk sample of 74 tonnes (from Block E) was mined and shipped to the Coal Research Laboratories. Figure 1 shows the general location and Figure 2 indicates how the sample was collected by leaving parts of the roof and floor in place of Block E.

Basic properties of the raw coal are shown in Table 1. Donkin-Morien coal is classified as high volatile, A bituminous coal according to the ASTM classification. The raw coal is low in ash but high in sulphur. The pyritic sulphur represents 55.3% of the total sulphur (dry basis). The sulphate sulphur content is relatively low (5.6% of total sulphur). Silica is the main component of ash followed by iron oxides (Table 2). Ash analyses of different clean coal products will be used to help in interpreting combustion results.

Two size ranges (as received minus 50 mm and crushed to minus 10 mm in the pilot plant crusher) are considered for coal characterization. The coarse size range (50 mm x 0) would represent coal commonly fed to a commercial preparation plant and the 10 mm x 0 is the size required for the pilot plant feed. The correlation between the two size ranges would help in relating the pilot plant results to a commercial scale preparation plant.

SIZE DISTRIBUTION

The relatively low Hardgrove Grindability Index (HGI = 57) indicates sufficient resistance to breakage. The amount of minus 0.6 mm generated by crushing the coal to two different top sizes (50mm and 10 mm) are 15.32% and 19.69% by mass respectively (Table 3). This indicates a limited increase (4.37%) in the amount of fines generated by crushing from 50 to 10 mm top size. The average particle size is reduced from 4.5 to 4.0 mm when the raw coal is crushed to minus 10 mm. No liberation in ash or sulphur is observed when comparing different size fractions before and after

crushing (Table 3). Ash contents for the two size ranges gradually increase with decrease in particle size. However, the variation in sulphur content between different size fractions is insignificant.

SIZE DEGRADATION

Size degradation of raw coal takes place during mining, handling and processing. Estimation of the amount of fines generated due to degradation is essential at an early stage of development for preparation plant design, dust control and handling of coal. Several direct and indirect methods are available to predict size degradation. The Australian wet attrition test is used to predict the amount of fines during handling and wet processing of the raw coal (2). The test treats raw coal on a laboratory scale under conditions simulating commercial wash plant treatment. A 50 kg sample of raw coal is tumbled with 150 kg water along with a standard number of steel cubes in a steel drum of 200 l capacity at 20 rpm. Tumbling duration is related to the raw coal Hardgrove Grindability Index; this time is usually between one and several minutes. Size distributions before and after attrition are compared to determine the degree of size degradation.

Attrition tests were carried out on two size ranges: the as received sample (minus 50 mm) and the crushed sample (minus 10 mm). The effect of wet attrition on size distribution, ash and sulphur contents of different size fractions is examined by comparing the before and after attrition data (Tables 4 and 5, Figs. 3 and 4).

The attrition tests indicated limited increase in the amount of fines due to degradation during attrition. The amounts of minus 0.6 mm increased from 15.3 to 16.8% and from 15.4 to 19.7% by mass for the minus 50 and minus 10 mm size ranges respectively. The amount of superfines (-45 μm) indicates insignificant increase as a result of wet attrition. Also, little change in ash and sulphur contents is observed as a result of wet attrition.

COAL STRUCTURE

The structure of coal includes pores and fissures of different

sizes which influence its chemical, physical and mechanical properties. Two areas of coal structure are considered relevant to this investigation: degree of fissuration as measured by the ΔP index and measurement of fine pyrite particles in the coal structure by using a scanning electron microscope.

ΔP Index

The experimental method is based on a technique originally developed to predict the susceptibility to gas outbursts in underground mines (3). The rate of gas release as measured by the ΔP index is related to the extent of fissuration in a coal. The ΔP index is used to predict the amount of fines generated during handling and processing (4). Also, it is an indication of the rate of release of gas (methane) from mined coal. The predicted amount of minus 0.6 mm in the run-of-mine (ROM) (ΔP=6.8) is 19.5% by mass, and is calculated from the following empirical equation (4).

$$\text{Mass \% of minus 0.6 mm in ROM} = 14.9 + 0.68\ \Delta P$$

The amount of minus 0.6 mm generated from wet attrition of the as received sample (minus 50 mm) is 16.8% by mass (Fig. 3). The difference between the two methods is 2.7%. The higher amount of fines (19.5%) predicted from the ΔP index measurement is recommended as it gives a better margin of safety in plant design.

Scanning Electron Microscopy

Coal samples are examined to observe the size and spatial distribution of fine pyrite particles (5). Figure 5a shows the presence of some pyrite particles along what appears to be a fissure of about 20 - 25 μm within the coal structure. Pyrite crystals (pockets) at higher magnification (Figure 5b) are approximately 5 μm in size with individual crystals of about 1 μm diameter. This indicates that to effectively liberate pyrite cluster of crystals, the coal has to be reduced in size to approximately 20 - 30 μm or less. Considering that pyrite only represent 52.3% of the total sulphur, grinding Donkin-Morien coal to less than 30 μm creates two problems:

1. Economic: The cost of grinding, cleaning and dewatering would be excessive;
2. Recovery: Separation of pyrite particles from coal would be difficult and less efficient than treating course particles.

WASHABILITY

Washability analysis were carried out on two size ranges of the minus 10 mm crushed coal after attrition: 10 x 0.6 mm and 0.6 x 0.15 mm (Tables 6 and 7). These washabilities represent the raw coal being fed to the pilot plant.

Washability data of the 10 x 0.6 mm fraction (Table 6) indicate, as expected sulphur content increases for higher relative density fractions. The less than 1.3 relative density fractions represent over 70% by mass of the raw coal, a distribution which is common for Sydney area coal seams. The raw coal can theoretically be cleaned to 2% ash or less with more than 85% recovery. A 50.1% sulphur removal can theoretically be achieved at a cutpoint of 1.325 with an 84% recovery of clean coal containing 1.8% sulphur (Fig.6).

The washability data for the 0.6 x 0.15 mm fraction (Table 7 and Fig. 7) is not significantly different from that of the 10 x 0.6 mm fraction for both ash and sulphur contents. A 31.5% sulphur removal can theoretically be achieved at a cutpoint of 1.50 with a 2.0% sulphur product at 93.5% recovery. A cutpoint of less than 1.50 is usually difficult to achieve by washing the 0.6 x 0.15 mm fraction in a water only density separator.

In practice, recoveries would be lower than the theoretical recoveries because of the inefficiency inherent in any process. Deviation between actual and theoretical recoveries is dependent on coal washability (near density material) and the systems used to wash the coal, some of which are more accurate in separation than others. Established computer models representing different systems and based on empirical data are used to predict quality and recovery of different products. Available computer models at CRL were used to predict recoveries from the above washabilities based on objectives mentioned earlier. The predictions are used to set parameters for pilot plant washing tests and as a measure of actual results. Figure 8 shows performance prediction at different cutpoints (dp's) for the

the heavy medium cyclone and jig as compared with the theoretical values based on coal washability data of the 10 x 0.6 mm fraction. A dp of 1.525 or less would be required to achieve 30% sulphur removal when a jig is used (Fig. 8). To achieve over 50% sulphur removal, a dp of 1.35 or less would be required when a heavy medium cyclone is used (jig use is not advisable for low dp's). The change in clean coal sulphur content between the high and low dp is only 0.50% sulphur which represent approximately 20% sulphur removal. At approximately 30% sulphur removal, the thermal recovery is expected to be over 95% (Fig. 9), while at 50% or more sulphur removal, the thermal recovery is approximately 85.5% or less.

HEAT VALUE/ASH RELATIONSHIP

The heat value (kJ/kg) of a particular coal can be expressed as a linear function of the ash content. The ash and thermal contents of different densities and size fractions are used to establish the following relationship (Appendix C).

$$kJ/kg\ (db) = 35302 - 428.5 * \text{Ash per cent.}$$

As shown in Fig. 9, both the low and high cutpoints can be achieved at relatively high thermal recovery containing 34575 and 34275 kJ/kg in clean coal respectively. This corresponds to 1.76 and 2.47% ash content in the clean coal products (Fig. C-1).

LIBERATION

The effect of crushing on ash and sulphur liberation is evaluated by reducing the top size from 50 mm (as received) to 10 mm. Two size ranges are considered in this report (plus 0.6 mm and 0.6 x 0.15 mm) to assess the effectiveness of crushing. These two size ranges are considered representative of cleaning in the coarse and fine circuits of a coal preparation plant (the fines circuit may include froth flotation for the 0.15 mm x 0 fraction which will be considered later in this report).

Ash Liberation

The relationship between average particle size and per cent ash shows little change in ash content with particle size (Fig. 10). Only the coarser fractions of the two size ranges (50 mm x 0 and 10 mm x 0) show a significant difference in ash content. The raw coal is relatively low in ash and the few high ash particles tend to segregate in the coarest fractions.The finest size fraction (-45 μm) shows little change in either ash or amount (by mass) as a result of crushing (Table 3).

Crushing the coal results in some liberation of ash (Table 8, Fig. 11) in the plus 0.6 mm fraction. The improvement in theoretical yield at different ash levels is not significant enough to justify crushing the raw coal from 50 to 10 mm top size, especially since the coal is very low in ash. Furthermore, washing finer particles would mean poorer separation that would offset the improvement in yield due to liberation. The fines (0.6 x 0.15 mm) fractions indicate significant change in their washability as a result of crushing (Fig. 12). However, the amount of fines formed during crushing was small and would not greatly influence the overall washability characteristics of the coal.

Sulphur Liberation

The relationship between average particle size and per cent sulphur shows little or no change in sulphur content with particle size (Fig. 10). Similar to ash, only the coarsest fractions of the two size ranges show some difference in sulphur content. It appears that high sulphur contents are associated with relatively high ash particles. However, this might change in the run-of-mine due to dilution with high ash barren rock.

Crushing to minus 10 mm indicates minor liberation in the plus 0.6 mm (Fig. 11). The theoretical improvement in content is 0.1% or less at a particular yield, depending on the cutpoint. Liberation for the 0.6 x 0.15 mm fraction is only observed at cutpoints less than 1.35 relative density (Fig. 12). However, above 1.35 little or no liberation can be achieved.

SURFACE CHARACTERISTICS OF FINE PARTICLES

Raw coal fine fractions (minus 0.6 mm) were tested in the laboratory to determine their flotation characteristics. Fine reject effluent (usually fed to a thickener) was also tested in the laboratory to determine its flocculation characteristics.

Flotation Testing

Bench scale flotation testing was carried out to select reagents and dosages that would give optimum recovery with sufficient ash and sulphur reduction. All flotation tests were run in a 2-litre conventional Denver laboratory flotation cell. Tests were run at 10% solids using distilled water. The coal was conditioned for 3 minutes before the addition of reagents. Froth samples were collected at 30, 60, 120 and 180 seconds after the introduction of air. Standard conditions for flotation are summarized in Table D-1.

Manipulated variables were flotation reagent type, dosage and flocculant dosage (to examine interaction between flotation and flocculation). The responding variables were ash and sulphur contents along with mass recovery. The reagents selected were kerosene, MIBC, Dowfroth M150, and Dowell froth conditioner M210. Kerosene and MIBC are widely used for coal flotation; M150 and M210 are intended to enhance the recovery of oxidized coals (Donkin-Morien coal was tested several months after being mined and was suspected to be oxidized). The flocculant used throughout the flotation testing was Percol E10 which was selected earlier as the best flocculant to treat Donkin-Morien effluent tailings. The flotation tests were carried out in two parts: with and without flocculant addition. Flotation results were evaluated by using an empirical formula called the efficiency index (5), which is defined as follows:

$$E = (Y * T)/C$$

where,

E = efficiency index
Y = % yield of clean coal
T = % ash or sulphur in tailings, and
C = % ash or sulphur in clean coal.

Residence Time: All results indicate that efficiency index of ash and sulphur increased with increasing residence time (Fig. 13 and 14). Also, the ash and sulphur contents in the froth increased with increasing residence time.

Reagents Dosage: Figure 13 indicates that at 180s residence time, the reagent combination (M150:M210): Kerosene gives the optimum (highest) ash efficiency index. This corresponds to 0.25 kg/tonne of (M150+M210) and 1.25 kg/tonne of kerosene. However, MIBC alone (followed by M150+M210:K) gave the optimum sulphur efficiency index, with corresponding dosages of 0.26 and 0.22 kg/tonne respectively (Fig.14). A summary of flotation test data and results is shown in Appendix D.

Ash and Sulphur Removal: An increase in residence time significantly improves froth recovery (Fig 13 and 14), however, with a concurrent increase in froth ash and sulphur (Fig. 16). Using MIBC produces a lower ash and sulphur content product than can be obtained by adding (M150+M210):K. Clean coal can be produced with 2.29% sulphur and 4.02% ash at 47.6% sulphur removal and 65.2% ash removal (Table 9). Ash and sulphur removal at different residence times for the (M150+M210):K and MIBC reagents are also shown in Table 9.

Effect of Flocculant Addition on Flotation: Bench scale tests were carried out to examine the effect of Percol E-10 flocculant on flotation efficiency index. The E-10 flocculant is the one selected for pilot plant testing. Varying amounts of E-10 (0-500 ppm) were added to the coal slurry before the flotation tests. The reagents that gave the best flotation results earlier were used here to examine flocculant influence on flotation. Results indicate that addition of up to 50 ppm of E-10 flocculant is beneficial to the flotation process (Fig. 17). Results also show however, that excessive amounts can cause deterioration in the flotation process.

Flocculation Testing

Bench scale flocculation testing was carried out at the CRL-Devon(7). The objective was to select a flocculant and determine the optimum dossage that would achieve a high settling rate and the required clarity (less than 100 ppm suspended solids). Several flocculants were tested; Percol E-10 (Allied Colloid) gave the best results. The optimum dossage of E-10 was 0.33 kg/tonne of tailings fed to the thickener. The slurry pH did not indicate any significant change in water acidity during the test due to leaching from coal.

PILOT PLANT EVALUATION

The Coal Research Laboratory pilot plant at Devon, Alberta consists of the five following sections:

1. Raw coal handling and crushing
2. Coarse cleaning
3. Fines cleaning
4. Dewatering
5. Water recovery

The pilot plant nominal capacity is between 2-10 tph depending on the circuits used. The plant contains various alternative circuits which can be pre-selected to treat different coals; 13 different flowsheet options are available (Fig. 17). The following are brief descriptions of the different sections of the plant (8).

COAL HANDLING AND CRUSHING

Raw coal (minus 100 mm) is unloaded into the raw coal hopper by means of a Bobcat loader. A 75 mm grid within the hopper prevents oversize material from passing to the primary Reddler conveyor. The oversize material is broken by hand either before or on the grid. Two primary Reddler conveyors feed the raw coal to a Ty-Rocket double deck vibrating screen

fitted with a 10 mm aperture. Oversize material from the screen passes to an impactor crusher (Hammermill) which crushes to pass 10 mm. The combined minus 10 mm (from the screen underflow and crushed coal) passes to the secondary Redler conveyor from where it is conveyed to the 10 tonne raw coal bin.

Raw coal is recovered from the bin by means of weigh belt feeder. The raw coal passes from the feeder to the raw coal tank where recirculated clarified water is added. The coal slurry is pumped to a desliming sieve bend and vibrating screen combination. The oversize (plus 0.5 mm) goes to the coarse cleaning and the undersize (minus 0.5 mm) to the fines cleaning circuits.

COARSE CLEANING

The oversize of the desliming screens can take two alternative routes: it can pass directly into the heavy medium cyclone circuit, or to a mixing tank. The coarse dewatered material is re-pulped in the mixing tank and then pumped to either the coarse Water-Only Tricone cyclones circuit or the Batac jig circuit.

a) Heavy Medium Cyclone Circuit

The deslimed coarse coal (plus 0.5 mm) passes to the H.M. feed tank to which magnetite powder is added via a feeder. The correct medium for separation together with raw coarse coal are pumped to a single 200 mm diameter D.S.M. heavy medium cyclone. Cleaned coal from the overflow is drained of magnetite by the sieve bend and the drain and rinsing screen. The second half of this screen is sprayed with fresh water to remove fine magnetite from the clean coal. Reject from the H.M. cyclone underflow passes to a sieve bend/screen, which similarly drains and rinses away magnetite.

Drained medium at the density of separation returns to the H.M. feed tank to be recirculated. Diluted medium from the sprayed section of each screen gravitates to the dilute medium tank to be pumped to the magnetic separator. The magnetic concentrate is mixed with correct medium and fed to the distribution box. By means of this distributor, a two-way splitter and a nuclear density gauge, the operational density of separation can be finely controlled during cleaning. Make-up magnetite, to compensate for losses incurred during operation, can be readily supplied by a dry powder feeder system (9).

Cleaned coal from the rinsing screen passes to the clean coal tank and is then dewatered in a centrifuge. The reject from the other rinsing screen is fed directly into barrels.

b) Ratac Jig Circuit

Raw coal is pumped from the mixing tank to a further stage of dewatering on a Sweco screen before being fed to the Ratac jig. Recirculated clarified water is supplied for jig operation. Clean coal overflowing from the jig passes to the clean coal sieve bend then to the clean coal tank. Middlings from the jig gravitate to the mixing tank for recirculation. The reject passes to the reject screen and then to barrels.

FINES CLEANING

The undersize of the desliming screens gravitates to the fines tank. The fines slurry can take two alternative routes: it can pass to the fine two-stage Tricone Cyclones or to the froth flotation cells.

a) Water-Only Tricone Cyclones

Fines slurry is pumped to the first stage of the fine coal Water-Only Tricone Cyclone (200 mm diameter). The overflow passes directly to the classifier cyclone (229 mm diameter Linatex Separator) which thickens the fine clean coal pulp before passing to a fines dewatering screen (Derrick screen 0.15 mm aperture) from which the damp cake overflow discharges to the clean coal tank. The primary cyclone underflow gravitates to a pump box (where water is added) to be pumped to the secondary stage cyclone. The secondary cyclone overflow is recirculated to the fine raw coal tank; underflow joins the thickener underflow and passes to the solid bowl centrifuge for dewatering.

b) Froth Flotation

The bank of six flotation cells is either pump fed from the fines tank when treating the minus 0.5 mm fraction or gravity fed from the classifying cyclone (Linatex separator overflow plus Derrick screen effluent) when treating the minus 0.15 mm fraction. Clean coal concentrates (froth) from all six cells gravitate to the clean coal tank. Tailings gravitate to the slimes tank, from where they are pumped to the high capacity thickener.

DEWATERING

Clean Coal: Both coarse and fine clean coals are combined in the clean coal tank before being dewatered in the pusher centrifuge. The dewatered clean coal is collected in barrels and the effluent recirculated to the raw coal tank.

Coarse Reject: The coarse reject is dewatered over a vibrating screen when using the Batac jig and over a rinsing screen when the heavy medium circuit is used. The coarse reject is collected in barrels and the effluent gravitates to the slimes tank or dilute medium tank in the case of the heavy medium circuit.

Fine Reject: The underflow of the thickener is fed to a solid bowl centrifuge. Dewatered tailings are collected in barrels and the centrifuge effluent pumped to the slimes tank for recirculation.

WATER RECOVERY

The classifying cyclone overflow (Linatex separator) or the flotation tailings, Derrick screen effluent (when flotation is not included) and the solids bowl centrifuge effluent are collected in the slimes tank. The slimes are pumped to the thickener feed box (deaeration tank) to minimize frothing in the bottom fed thickener. Flocculant addition is controlled using a metering pump then diluted before being mixed with the slimes fed to the thickener. The clarified overflow of the thickener is pumped to a make-up water tank for recirculation. The thickener underflow slurry is pumped to the solid bowl centrifuge for dewatering.

SELECTION OF FLOWSHEET OPTIONS

Based on objectives described earlier three flowsheet options were selected. These objectives are summarized as follows (Table 10):

a) Maximum thermal recovery (90-95%) at 30-35% sulphur reduction.
b) Low cutpoint to achieve 50% or more sulphur reduction at reasonable thermal recovery.
c) Maximize sulphur reduction (over 50%) at cutpoint less than 1.30.

Batac Jig, Water-Only Tricone Cyclones and Froth Flotation Flowsheet

The crushed raw coal (minus 10 mm) is fed to the plant at a controlled rate by using a weigh feeder. The raw coal is pulped and deslimed over a sieve bend and a vibrating screen. The 10 x 0.5 mm fraction is repulped and pumped to a dewatering screen (Sweco) before being fed to the Batac jig. The clean coal is dewatered over a sieve bend before gravitating to the clean coal tank. The reject is fed to a dewatering screen before being collected in drums. The middlings is sent to the mixing tank for recirculation with the raw coal to the jig.

The minus 0.5 mm fraction from the desliming screen is fed to a two stage Water-Only Tricone cyclone system. The overflow of the primary cyclone is dewatered in stages: classifying cyclone followed by a Derrick screen. Effluents from the classifying cyclone and Derrick screen are fed to a bank of flotation cells. The froth product is fed to the clean coal tank. Flotation tailings are clarified in a bottom fed thickener and the clarified water recirculated.

The dewatered fine clean coal from the Derrick screen is combined with the coarse clean coal in the clean coal tank, dewatered in the pusher centrifuge and collected in barrels as clean coal. The underflow of the thickener is dewatered in the solid bowl centrifuge and collected in barrels as fine reject (Fig. 19).

Heavy Medium Cyclone, Water-Only Tricone Cyclones and Froth Flotation Flowsheet

In this flowsheet the heavy medium cyclone replaces the Batac jig for coarse cleaning (Fig. 20). The heavy medium cyclone circuit was described earlier. The rest of the flowsheet is the same as the above option.

PILOT PLANT TESTING

After the initial adjustment of different units, a short preliminary run was made and samples collected for analysis to determine if further adjustment of the equipment is required. This is done for all

flowsheet options discussed earlier. After achieving the predicted results, long runs were performed to produce the required tonnage of clean coal for combustion tests and to collect samples during stable operating conditions. Incremental and timed samples were taken from intermediate and end products to evaluate the overall performance and determine the material balance of the plant. All products (clean coal, coarse and fine rejects) were weighed and corrected for moisture to determine weight of products on a dry basis.

Ash, moisture, sulphur and heat value were determined for the feed and the final products (clean coal, coarse and fine rejects). Intermediate samples were analyzed for ash, sulphur and per cent solids. These data were used to establish material balance of different flowsheet options. Screen and float-sink analysis were performed on feed and products of cleaning units to evaluate their performance.

Approximately 35t of raw coal with less than 8.24% ash, 3.40% sulphur and 3.90% moisture were used in the pilot plant for preliminary and long runs. Some of the long runs had to be repeated due to difficulties in adjusting heavy medium cyclone and other equipment. Optimum flotation reagents determined in the bench scale tests were used in the pilot plant. Table 11 shows a summary of results for preliminary and long runs. Sampling data (Tables 12, 13 and 14) were used to calculate material balance of the three flowsheet options (Figs. 21, 22 and 23).

DISCUSSION OF RESULTS

Donkin-Morien raw coal is low in ash and can be easily reduced to 2 or 3% ash in clean coal by cleaning in any system at relatively high cutpoints. This characteristic is common with many Sydney area coal seams. However, significant sulphur reduction is not as easy to achieve and requires low cutpoints. Three test runs (tests 2, 7 and 9) were selected out of a total of 9 runs to represent the required flowsheet options. Results are summerized in Table 15. The first option (test 2) emphasizes ash reduction at high cutpoint with limited sulphur reduction, while the other two options (test 7 and 9) seek deeper reduction in ash and sulphur. The data in Tables 12, 13 and 14 representing the three options indicate that the sulphur content of clean coal is strongly influenced by changes in the coarse

cleaning section cutpoint. Water-only cyclone and froth flotation clean coal products do not show significant changes in sulphur content by varying the cutpoint or amount of reagent addition. This is probably due to the fact that fines are usually cleaned at cutpoints higher than 1.60 and the amount of material in the relative density range of 1.5 to 2.17 is only 3.45% of the 0.6 x 0.15 mm fraction. The coal slimes (0.15 mm X 0) are easy to float. However, when reagent addition is lowered to reduce entrapment of sulphur particles in thick froth, the tailings produced are relatively low in ash (21.8 - 39.69% ash) with no significant increase of sulphur.

The amount of fines fed to the water recovery section is significantly low (0.07 - 0.64% solids). As a result, minimum (less than half of laboratory optimum dossage) amounts of flocculant are required to produce consistently clear water for recirculation. No change in water pH was observed during the testing of Donkin-Morien coal due to acid leaching from oxidized pyrite or sulphate sulphur present in the coal. The solids content in the thickener underflow was very low due to the small amounts of tailings reporting to the thickener.

FLOWSHEET OPTIONS COMPARISON

The main difference between the three options is the coarse cleaning circuit. In the fine circuit, the cutpoint of the primary cyclone and reagent addition to froth flotation are the main variables. Dewatering circuit is the same for the three options. The feed rate to the jig is higher (0.3-0.5 tph) than for the heavy medium cyclone options.

The differences between the reconstituted feed (by combining products) and raw feed ash and sulphur content is relatively small. It can be caused by variation in coal quality during runs, sampling and analyses. These differences are within the acceptable experimental error (see Figs. 21, 22 and 23). The limited amount of fines in the raw coal helped the overall recovery by minimizing the amount of recirculated fines in the system.

Clean coal sulphur contents were 2.49% for test 2, 1.96% for test 7 and 1.74% for test 9 (Table 15) with corresponding yields of 91.6, 65.4 and 64.0% respectively. The calculated sulphur removal =

$$100 - \frac{(\text{Clean Coal Sulphur} \times \text{Yield})}{\text{Raw Coal Sulphur}}$$

ranges between 33.9% for test 2 and 65.1% for test 9. The thermal recovery =

$$\frac{\text{(Clean Coal kJ/kg x Yield)}}{\text{Raw Coal kJ/kg}}$$

ranges between 95.8% for test 2 and 66.9% for test 9. The significant differences between the three parameters (yield, thermal recovery and sulphur removal) for the three tests can be traced to the coarse cleaning circuit. The low ash content of the reject products (Table 15) along with low thermal recovery at low cutpoints demonstrate the need to consider a middlings product to improve the overall thermal recovery.

EQUIPMENT PERFORMANCE

The main reason for measuring the performance of coal washing equipment is to establish whether a unit is operating satisfactorily or whether better performance should be expected. Performance parameters can conveniently be classified according to the degree to which they are dependent on the relative density of the raw coal being treated (10). Organic efficiency, thermal recovery, ash and yield errors are identified as dependent on the coal washability. Performance parameters such as the probable error and error area are characteristic only of the washing equipment and are independent of the coal washability. These parameters (independent) are derived from the conventional error curve which gives the proportion of the feed reporting to the reject product at given relative density values. By definition, dp is the relative density corresponding to the 50% ordinate while the probable error (Ep) is one-half the difference between the relative densities corresponding to the 25 and 75 per cent ordinates. The error area is the area laying between the actual error curve and the line (vertical) representing a perfect separation. The lower the probable error or error area is, the steeper the curve and the sharper the separation (10).

Batac Jig

The feed rate to the jig was 1.92 tph (not including recirculated middlings) with ash and sulphur contents of 5.60 and 3.33% respectively (Table 16). The jig produced a yield of 93.63% at 1.73 dp with 2.98% ash and 2.40% sulphur in the clean coal. Organic efficiency and thermal recovery values of 99.52 and 96.83% respectively are comparable to originally set objectives for high thermal recovery. Yield (0.45) and ash (0.13) errors are low due to the limited amounts of near density material (1.39%) at dp 1.73. Ash and sulphur removal are 49.82 and 32.52% respectively.

The probable error is 0.20 with corresponding error area of 105 (Fig. 24). Previous tests using the Batac jig gave Ep's of 0.10-0.15. The relatively poorer separation than expected is probably due to:

a) Small amounts of heavy material (>1.80 relative density) that did not allow the formation of a sufficient bed and resulted in a higher dp than originally set due to lifting of fine heavy fractions by the upward flowing water.

b) High amount of water being fed to the jig, caused by the malfunction of the valve that regulates the water feed rate to the jig.

Heavy Medium Cyclone

The heavy medium cyclone was used in two runs to maximize sulphur removal. One test was aimed at dp between 1.30-1.35 and the other between 1.275-1.30. The feed rates were 1.63 and 1.70 tph for test 7 and 9 resulting in yields of 80.04 and 60.83% respectively (Table 16, Figs. 22 and 23). As expected both organic efficiency and thermal recovery are relatively low and yield error relatively high due to low cutpoints (Table 16) and large amounts of near density material.

The probable error for the two tests is 0.03 with corresponding error areas of 22 (test 7) and 20 (test 9) at cutpoints of 1.33 and 1.28 respectively (Figs. 25 and 26). The cyclone performance is excellent and

comparable to what might be expected in an operating plant under optimum conditions. This resulted in good sulphur removals of 47.46% (test 7) and 69.39% (test 9) with less than 2% ash and sulphur in the clean coal. In test 9 the ash content is 1.16% with corresponding sulphur of 1.57% in the clean coal at a reasonable yield of 60.83%.

Water-Only Tricone Cyclones (Fines)

The feed rate to the two stage cyclones was 0.77-1.0 tph and produced clean coal yield of 96.39% with 2.48% ash and 2.05% sulphur at 2.03 dp (Table 17). Organic efficiency (98.29%) and thermal recovery (98.27%) at 2.03 dp is considered good in treating 0.6 x 0.15 mm size coal. Yield (2.12) and ash (0.16) errors are within acceptable limits. Sulphur removal (20.96%) is limited at a high cutpoint of 2.03 due to the small proportion of material heavier than 2.03.

The probable error of 0.25 and corresponding error area of 132 are high (Fig. 27) and indicate less than expected performance. This probably is caused by the small amounts of heavy fractions, which is not sufficient to form the bed in the cyclone required for effective density separation.

Froth Flotation

Donkin-Morien coal (0.15 mm x 0) is easy to float and produces high quality clean coal. The feed rate to a bank of six Denver flotation cells was 0.44 tph and produced a clean coal (froth) yield of 82.5% with 3.35% ash and 2.20% sulphur (Table 18). Thermal recovery (90.0%) and ash (69.3%) and sulphur (41.8%) removal indicate good performance. Also, the efficiency index (884) is slightly higher than the best results achieved in the laboratory (discussed earlier). Usually pilot plant or plant results indicate lower ash and yield than laboratory work. This is due to the reduced agitation and aeration in large cells which makes the flotation process more selective.

Comparison Between the Performance of Heavy Medium Cyclone and Jig Circuits

Donkin-Morien raw coal is exceptionally low in ash content. Sulphur removal is the issue for cleaning rather than ash reduction. For maximum sulphur reduction (i.e. low dp), the heavy medium cyclone is the only system capable of achieving the task efficiently. However, if the objective is to maximize thermal recovery at 30-35% sulphur removal then the jig circuit would be more favourable provided the raw coal is higher in ash than the treated bulk sample. Unless there is sufficient high density material to form a bed, the jig's performance is expected to be impaired.

Washing the coarse coal (+0.6 mm) at low dp to maximize sulphur removal would result in low thermal recovery as a result of low ash reject. A possible alternative to maximize sulphur reduction is to get a premium high quality coal and produce a secondary product with limited sulphur reduction to maximize the overall thermal product. To achieve that, a two stage system is required. A two stage heavy medium cyclone would be advisable in treating low ash raw coal where the secondary stage would be limited in capacity. However, if a higher ash content in the raw coal is expected (e.g. 15% or higher), a combination of a heavy medium system to produce the premium product at low dp and a water only system (e.g. jig) treating the underflow of the primary circuit (heavy medium) to give the secondary product at high dp (1.60-1.80) would be required. This option would combine the advantages of the two systems to maximize the production of marketable products.

BENEFICIATION POTENTIAL AND COMMERCIAL SCALE UP

Laboratory and pilot plant investigations produced data that help understand and predict what can be achieved by upgrading Donkin-Morien Coal. Potential and limitations of beneficiating the coal are essential for future development. Parameters such as liberation, amount of fines to be treated and expected sulphur reduction are briefly discussed below in relation to possible commercial scale up.

LIBERATION

Crushing the raw coal from 50 to 10 mm top size does not indicate improvement in ash or sulphur liberation. Therefore to maximize thermal recovery and minimize preparation cost, the coal should be washed as coarse as practically feasible (100 or 50 mm top size). Fortunately, heavy density fractions are the highest in sulphur content and at any dp, the clean coal stands to be lower in sulphur. Organic sulphur in the raw coal is 1.31% which is approximately the same as the sulphur in the lowest density fraction (1.29%). Organic sulphur is usually evenly distributed in the coal structure and is not liberated from it by crushing.

AMOUNT OF FINES FOR TREATMENT

The amount of minus 0.6 mm from the minus 50 mm crushed coal is expected to be 19.5% by mass. This prediction is based on ΔP measurement and includes the fines generated during mining, handling and processing. The amount of fines generated from the wet attrition test is 16.8%. However, it is advisable to use the higher value (19.5%) for design purposes. No change in the amount of super-fines (-45 μm) is observed as a result of wet attrition (before 4.59%, after 4.81%).

SULPHUR REMOVAL AND FLOWSHEET SELECTION

The washability characteristics and pilot plant testing of Donkin-Morien coal indicate that 30-65% sulphur removal can be achieved at commercially acceptable recoveries. Three flowsheet options can be considered depending on the desired level of sulphur removal and economically acceptable thermal recovery. Table 19 shows the flowsheet options in relation to approximate levels of thermal recoveries and sulphur removal. A high quality very low ash (1.5-2%) with less than 2% sulphur coal can be produced through option 2 or 3. Option 3 gives more flexibility for changing market and environment regulations. This enables the operator to adjust the quality of the primary and the secondary products to meet market needs and to achieve an overall high thermal recovery.

CONCLUSIONS

COAL CHARACTERISTICS

1. Donkin-Morien coal is relatively low in ash (8.24%) but high in sulphur (3.40%) of which 55.3% (of the total sulphur) is pyritic and 5.6% sulphate with the balance (39.1%) as organic sulphur. The coal is relatively hard (HGI = 57) and produces a limited amount of fines (minus 0.60 mm) during crushing.

2. When wet attrited the raw coal generated limited increase in the amount of fines (15.3% to 16.8% by mass of minus 0.6 mm for the minus 50 mm size) 17.1% of which is minus 45 μm. Little or no change in ash and sulphur contents is observed as a result of wet attrition of the minus 10 mm size.

3. The amount of fines (minus 0.6 mm) in the minus 50 mm coal is expected to be 19.5% by mass. This was predicted from ΔP index (measurement of the degree of coal fissuration) which was slightly higher than the one measured by the wet attrition test (16.8%).

4. Scanning electron microscopy investigation indicates that the coal requires grinding to approximately 30 μm or less to achieve effective liberation of fine pyrite particles. However, present economic and technical factors make it difficult to justify grinding the coal to that fine particle size.

5. Washability data of coal crushed to minus 10 mm indicate that the sulphur content increases with increasing relative density. The raw coal (10 x 0.6 mm) can theoretically be cleaned to 2% ash or less with over 80% mass recovery. Also, a 50% sulphur removal can be achieved at 1.325 cutpoint with 1.8% sulphur at 84% by mass recovery of clean coal. For the 0.6 x 0.15 mm, a 31.5% sulphur removal can theoretically be achieved at 1.50 cutpoint with 2% sulphur at 93.5% by mass recovery.

6. Based on crushing data (from 50 to 10 mm top size), size reduction of coal has little effect on size ranges considered for treatment in a wash plant (+0.6 mm and 0.6 x 0.15 mm). Moderate ash and limited sulphur liberation are observed as a result of crushing. Crushing the coal to liberate sulphur is not advisable as it translates to a reduction of 0.1% or less in sulphur content of the clean coal at practical yields.

7. Donkin-Morien coal is an easy to float coal; however, it requires about 3 minutes residence time to achieve high recovery. MIBC reagent gave the best recovery at 0.13 kg/tonne dosage. Bench scale results indicated that a froth product with 2.29% sulphur and 4.02% ash at 74.6% recovery by mass can be achieved. This corresponds to 47.6 and 65.2% sulphur and ash removal respectively. Flocculant Percol E-10 (Allied Colloids) gave the best settling rates in clarifying flotation tailings. Results indicated that traces of the above flocculant in the recirculated water (up to 50 ppm) can be beneficial to flotation; however, excessive amounts can cause deterioration in the flotation process.

PILOT PLANT TESTING

Two flowsheet options were selected based on three objectives a) maximum thermal recovery at limited sulphur removal b) lower sulphur in clean coal to 2% or less c) maximum sulphur removal at acceptable mass recovery. The first option for objective (a) included Batac jig for coarse coal (10 x 0.5 mm), two stage water-only cyclones for the 0.5 x 0.15 mm and froth flotation for the 0.15 mm x 0. The second option for objectives (b) and (c) includes heavy medium cyclone for coarse coal instead of the Batac jig; the fine coal is as in option one. A total of approximately 35 tonnes of raw coal was processed in the pilot plant and produced three large samples (approx. 5 t) for combustion testing.

PILOT PLANT RESULTS

1. The three main pilot plant runs produced clean coal with sulphur removal of 33.9 to 65.1% at corresponding thermal recoveries of 95.6 to 64.0% respectively.

2. The Batac jig operating at a relative density of separation (dp) of 1.73 gave an Ep of 0.20 and an organic efficiency of 99.5%. The relatively poor separation (Ep = 0.20) in the Batac jig is probably due to insufficient amounts of heavy particles to form a stable bed in the jig and high amounts of water being fed to the jig caused by the malfunction of a regulating valve.

3. The heavy medium cyclone gave a good performance at two low cutpoints (dp) of 1.33 and 1.28 with a sharp separation of 0.03 Ep and organic efficiencies of 92.9 and 90.7% respectively. The heavy medium cyclone is the only system capable of achieving efficient separation at very low cutpoints.

4. The Water-Only Tricone Cyclones (fines) performance was marginal and gave an Ep of 0.27 with organic efficiency of 98.3% at 2.03 dp. The less than expected performance was probably caused by the small amounts of heavy material in the raw coal; i.e. not enough to form the bed required for effective density separation in the cyclone.

5. Pilot plant flotation cells performed similarly to the bench scale tests. Flotation produced a clean coal mass recovery of 82.5% with 3.25% ash and 2.2% sulphur at an ash efficiency index of 884.

6. No change in the pH of recirculated water was observed due to leaching of sulphate. The water recovery circuit produced clarified water at minimum addition of flocculant.

BENEFICIATION POTENTIAL AND COMMERCIAL SCALE UP

Donkin-Morien is amenable to significant reduction in ash (1-2% in clean coal) and moderate reduction in sulphur (1.5-1.9%) by crushing to commercially applicable particle sizes, e.g. 50 mm top size. At this size range, the amount of minus 0.6 mm in the processed coal is expected to be 19.5%, which is similar to the Lingan coal presently washed at Cape Breton Development Corporation, Victoria Junction preparation plant.

Three flowsheet options are suggested to give between 30 and 65% sulphur removal. Two of three flowsheet options were tested on a pilot plant scale, one is capable of 30-40% sulphur removal at maximum thermal recovery (95%) and the other would achieve 60 to 65% sulphur removal at lower recovery (65-70%). A third option is suggested for consideration to maximize both sulphur removal and thermal recovery. This option would include a two stage system for coarse cleaning to produce a premium product low in ash and sulphur and a secondary product relatively higher in ash and sulphur. That option would give more flexibility in meeting changing market conditions and environmental regulations.

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Table 1 - Bulk sample: Donkin-Morien raw coal quality

	As Received Basis	Dry Basis
Moisture (%)	3.90	----
Ash (%)	7.92	8.24
Volatile Matter (%)	34.21	35.60
Fixed Carbon (%)	53.97	56.16
kJ/kg	30547	31787
Total Sulphur (%) *	3.26	3.40
Pyrite Sulphur (%) *	1.80	1.88
Sulphate Sulphur (%) *	0.18	0.19
Organic Sulphur (%)	1.28	1.33
Pyritic/Total (%)	55.21	52.29
Sulphur (kg/MkJ)	1.07	1.07
SO_2 (kg/MkJ)	2.14	2.14
Hardgrove Grindability Index	57	
Ultimate Analysis (%) *		
H_2O	1.17	----
C	74.75	75.63
H	4.88	4.81
N	1.39	1.41
Ash	8.14	8.24
S	3.36	3.40
O (difference)	7.48	6.51

* Air dried

Table 2 - Elemental ash analysis of raw Donkin-Morien coal

Constituent	WT %
$Si0_2$	35.75
Al_20_3	21.07
$Ti0_2$	0.43
Fe_20_3	31.35
CaO	5.14
MgO	0.52
Na_20	0.71
K_20	0.64
P_20_5	0.25
$S0_3$	2.02
Undetermined	2.12

Table 3 - Effect of crushing on size distribution characteristics.

Screen Fractions (mm)	Raw Coal crushed to minus					
	50 mm			10 mm		
	Mass %	Ash %	S %	Mass %	Ash %	S %
Plus 0.6	84.68	5.23	3.08	84.64	6.37	3.48
0.6-0.15	7.22	6.03	2.79	7.80	6.12	2.69
0.15-0.075	2.29	8.22	2.92	2.23	8.22	2.95
0.075-0.045	1.22	8.81	3.16	1.13	9.33	3.10
Minus 0.045	4.59	12.65	3.15	4.20	12.75	2.93
Total	100.00	5.74	3.06	100.00	6.69	3.38

Note: variation in ash and/or sulphur is due to error in obtaining a representative sample from the 74 t bulk sample.

Table 4 - Size degradation by wet attrition - 50 mm top size.

Screen Fractions (mm)	Before attrition			After attrition		
	Mass %	Ash %	S %	Mass %	Ash %	S %
Plus 25.0	2.61	12.28	5.58	3.32	3.25	1.72
25.0-9.5	20.98	4.88	3.05	18.56	7.71	3.79
9.5-6.7	12.62	4.93	2.68	12.83	6.10	3.09
6.7-1.7	36.09	4.89	3.08	37.25	5.09	2.98
1.7-0.60	12.38	5.65	2.99	11.24	4.98	2.71
0.60-0.30	4.10	5.59	2.79	5.13	4.05	2.32
0.30-0.15	3.12	6.60	2.79	3.27	6.08	2.47
0.15-0.075	2.29	8.22	2.92	2.26	7.73	2.77
0.075-0.045	1.22	8.21	3.16	1.33	8.20	2.88
Minus 0.045	4.59	12.65	3.15	4.81	13.84	2.86
Total	100.00	5.74	3.06	100.00	6.13	3.01

Table 5 - Size degradation by wet attrition - 10 mm top size.

Screen Fractions (mm)	Before attrition			After attrition		
	Mass %	Ash %	S %	Mass %	Ash %	S %
Plus 12.5	2.19	8.85	3.27	2.21	8.64	4.13
12.5-6.7	26.12	8.34	4.67	23.80	5.12	3.11
6.7-1.7	42.00	5.30	3.00	40.13	4.96	2.95
1.7-0.60	14.33	5.52	2.78	14.17	5.31	2.92
0.60-0.30	4.62	5.65	2.65	6.21	5.57	2.79
0.30-0.15	3.18	6.80	2.76	3.99	6.89	2.83
0.15-0.075	2.23	8.22	2.95	2.77	8.12	3.02
0.075-0.045	1.13	9.33	3.10	1.75	8.64	2.99
Minus 0.045	4.20	12.75	2.93	4.97	13.61	3.07
Total	100.00	6.69	3.38	100.00	5.83	3.00

Table 6 - Washing Characteristics of Donkin-Morien crushed coal after wet attrition -10 x 0.6 mm (80.31% of total)

Relative Density Fractions	Elementary Data				Cumulative Float Data				Cumulative Sink Data			
	Mass%	Ash%	S%	kJ/kg	Mass%	Ash%	S%	kJ/kg	Mass%	Ash%	S%	kJ/kg*
Float-1.250	2.26	0.71	1.05	35653	2.26	0.71	1.05	35653	100.00	5.79	3.03	33010
1.250-1.275	39.20	0.69	1.16	35145	41.46	0.69	1.15	35173	97.74	5.91	3.07	32948
1.275-1.300	32.00	2.47	2.13	34307	73.46	1.47	1.58	34796	58.54	9.41	4.36	31478
1.300-1.350	12.19	5.08	3.43	33248	85.65	1.98	1.84	34575	26.54	17.77	7.04	28066
1.350-1.400	4.40	9.27	4.96	31612	90.05	2.34	1.99	34431	14.35	28.56	10.11	23664
1.400-1.450	2.69	12.87	7.43	29998	92.74	2.64	2.15	34302	9.95	37.08	12.39	20150
1.450-1.500	1.05	17.71	9.03	28058	93.79	2.81	2.23	34232	7.26	46.06	14.22	16500
1.500-1.600	1.07	22.35	10.38	26337	94.86	3.03	2.32	34143	6.21	50.85	15.10	14546
1.600-1.800	1.30	30.88	12.64	22947	96.16	3.41	2.46	33992	5.14	56.78	16.08	12092
1.800-2.000	0.65	39.40	16.82	19185	96.81	3.65	2.56	33892	3.84	65.55	17.25	8417
2.000-2.170	0.38	46.55	18.77	15983	97.19	3.82	2.62	33822	3.19	70.88	17.33	6223
Sink -2.170	2.81	74.17	17.14	4903	100.00	5.79	3.03	33010	2.81	74.17	17.14	4903

Table 7 - Washing Characteristics of Donkin-Morien crushed coal after wet attrition 0.6 x 0.15 mm (10.20% of total).

Relative Density Fractions	Elementary Data				Cumulative Float Data				Cumulative Sink Data			
	Mass%	Ash%	S%	kJ/kg	Mass%	Ash%	S%	kJ/kg	Mass%	Ash%	S%	kJ/kg*
Float-1.275	24.96	0.48	1.29	34926	24.96	0.48	1.29	34926	100.0	5.19	2.73	32805
1.275-1.300	32.45	0.80	1.38	34638	57.41	0.66	1.34	34763	75.04	6.76	3.20	32100
1.300-1.350	27.78	2.62	2.44	33788	85.19	1.30	1.70	34445	42.59	11.30	4.59	30166
1.350-1.400	4.68	5.35	3.81	32619	89.87	1.51	1.81	34350	14.81	27.57	8.64	23372
1.400-1.500	3.64	14.15	7.68	29946	93.51	2.00	2.04	34179	10.13	37.84	10.86	19100
1.500-1.800	2.22	30.35	11.28	23351	95.73	2.66	2.25	33928	6.49	51.12	12.65	13017
1.800-2.170	1.23	43.61	13.15	16806	96.96	3.18	2.39	33710	4.27	61.92	13.36	7644
Sink-2.170	3.04	69.33	13.45	3937	100.00	5.19	2.73	32805	3.04	69.33	13.45	3937

*Calculated.

Table 8 - Effect of crushing on liberation in plus 0.6 mm fraction.

Relative Density Fractions	Raw Coal crushed to minus					
	50 mm			10 mm		
	Mass %	Ash %	S %	Mass %	Ash %	S %
Float-1.250				2.26	0.71	1.05
1.250-1.275	35.11	0.98	1.29	39.20	0.69	1.16
1.275-1.300	33.44	1.92	1.90	32.00	2.47	2.13
1.300-1.350	15.02	5.50	3.47	12.19	5.08	3.43
1.350-1.400	4.28	9.19	5.04	4.40	9.27	4.96
1.400-1.450	2.16	12.31	6.21	2.69	12.87	7.43
1.450-1.500	1.19	16.28	7.48	1.05	17.71	9.03
1.500-1.600	1.11	21.24	8.73	1.07	22.35	10.38
1.600-1.800	1.26	29.91	10.93	1.30	30.88	12.64
1.800-2.000	0.83	37.77	13.56	0.65	39.40	16.82
2.000-2.170	0.51	47.75	15.22	0.38	46.55	18.77
Sink-2.170	5.09	65.84	27.34	2.81	74.17	18.77
Total	100.00	7.19	3.86	100.00	5.79	2.93

Table 9 - Ash and sulphur removal by froth flotation.

Reagents	Residence Time Seconds	Cumulative			Ash Removal %	Sulphur Removal %
		Mass %	Ash %	Sulphur %		
(M150+M210):K	0 - 30	75.07	4.49	2.58	60.62	41.83
Ratio (1:1):5	30 - 60	84.41	4.79	2.65	52.93	32.83
0.06 kg/tonne	60 - 120	88.48	5.00	2.70	48.50	28.26
	120 - 180	90.93	5.35	2.75	43.30	24.91
	0 - 30	74.55	4.02	2.29	65.19	47.63
MIBC	30 - 60	86.36	4.66	2.47	53.26	34.57
0.13 kg/tonne	60 - 120	89.90	5.14	2.58	46.33	27.47
	120 - 180	91.04	5.43	2.63	42.58	26.55

Table 10 - Summary of pilot plant testing objectives.

Objective	Cleaning methods for different size fractions		
	+0.5 mm	0.5 X 0.15 mm	0.15 mm X 0
Maximum thermal recovery (90-95%) with moderate sulphur reduction	Batac Jig	Two stage Tricone cyclone	Froth Flotation
Reduce sulphur content to about 2% at dp of 1.35-1.40	Heavy medium cyclone	Two stage Tricone cyclone	Froth Flotation
Maximum reduction of sulphur at dp of less than 1.30	Heavy medium cyclone	Two stage Tricone cyclone	Froth Flotation

Table 11 - Summary of pilot plant testing results.

Test No.	System	Raw Coal			Clean Coal			Coarse reject			Fine reject			Clean Coal Yield %	Thermal recovery%
		RM %	A %	S %	RM %	A %	S %	RM %	A %	S %	RM %	A %	S %		
1	Batac jig, Tricone Cyclones and	3.68	8.09	3.57	9.29	3.62	2.49	14.50	43.92	14.26	6.42	43.37	13.96	95.37	100
2	Froth Flotation	3.23	6.76	3.45	7.70	3.27	2.49	12.80	53.38	17.28	12.29	39.96	12.19	91.56	95.80
3	Heavy medium	3.40	7.37	3.62	8.60	3.06	2.14	27.09	41.93	14.58	10.69	35.25	10.37	88.05	93.11
4	cyclone,	2.60	6.87	3.65	9.52	3.30	2.30	23.29	42.49	14.17	13.82	34.60	7.05	87.43	91.56
5	Tricone	3.32	6.92	3.61	8.76	2.32	2.06	28.80	26.22	9.23	14.79	20.97	5.37	74.27	78.80
6	cyclones	----	----	----	8.33	2.06	2.01	-----	-----	-----	----	----	--- -	-----	-----
	and														
7	Froth	2.67	5.35	3.21	9.68	2.04	1.96	32.84	20.14	8.58	16.66	19.19	4.82	65.43	68.24
8	Flotation	3.67	6.59	3.44	13.15	1.98	1.77	34.11	8.15	3.00	17.84	24.14	6.65	45.94	48.73
9		3.42	5.35	3.19	7.37	1.85	1.74	32.91	13.68	5.46	17.35	24.14	7.22	64.00	66.93

RM = Moisture, A = Ash (db), S =Sulphur (db)

Note: variation in raw coal ash and sulphur is a result of the bulk sample (mined from different sections of the tunnel - Fig. 2) was not homogenized at the mine site.

Table 12 - Analysis of products from different circuits -Test 2

Feed and Products

	% Moisture	% Ash	% Sulphur	Specific Energy (MJ/kg)	Recovery Mass (t)	Recovery Mass %
Feed	3.23	6.76	3.45	32.42	5.93	100.00
Clean Coal	7.70	3.27	2.49	33.92	5.43	91.57
Coarse Rejects	12.80	52.38	17.28	12.81	0.37	6.24
Fine Rejects	12.29	39.96	12.19	18.15	0.13	2.19

Coarse Cleaning (Batac Jig)

	% Solids	% Ash	% Sulphur
Deslime Screen Overflow	69.51	6.02	3.29
Clean Coal	64.18	2.97	2.46
Rejects	73.50	48.93	15.57

Compound Water Only Cyclone Circuit

	% Solids	% Ash	% Sulphur
Deslime Screen Underflow	3.58	6.90	3.40
CWC OU (Clean Coal)	32.03	4.12	2.58
CWC UU (Rejects)	12.79	51.75	15.77
Linatex Overflow	1.12	7.77	2.64
Linatex Underflow	13.58	5.50	2.98
Derrick Screen Underflow	4.10	17.92	6.14

Froth Flotation

	% Solids	% Ash	% Sulphur
Feed	1.51	10.30	3.58
Product from Cell 1	20.18	3.79	2.30
Product from Cell 2	7.58	6.30	2.95
Tailings	NA	39.69	6.73

Dewatering Circuit

	% Solids	% Ash	% Sulphur
Thickener Feed	0.07	35.42	5.76
Thickener Overflow	0.01	41.25	5.56
Thickener Underflow	0.81	53.61	13.68
Clean Coal Centrifuge Effluent	5.16	4.63	2.64
Fine Reject Centrifuge Effluent	0.25	36.02	3.73

Note: Ash, Sulphur and Mass are reported on a dry basis.

Table 13 - Analysis of products from different circuits -Test 7

Feed and Products

	% Moisture	% Ash	% Sulphur	Specific Energy (MJ/kg)	Recovery Mass (t)	Recovery Mass %
Feed	2.67	5.35	3.21	33.03	4.05	100.00
Clean Coal	9.68	2.04	1.96	34.45	2.65	65.43
Coarse Rejects	32.84	20.14	8.58	26.67	1.04	25.67
Fine Rejects	16.66	19.19	4.82	27.08	0.36	8.90

Coarse Cleaning (Dense Medium Cyclone)

	% Solids	% Ash	% Sulphur
Deslime Screen Overflow	68.77	5.42	3.34
Clean Coal	70.05	1.89	1.89
Rejects	73.59	19.96	8.27

Compound Water Only Cyclone Circuit

	% Solids	% Ash	% Sulphur
Deslime Screen Underflow	3.67	5.29	2.43
CWC OU (Clean Coal)	27.12	3.19	2.30
CWC UU (Rejects)	7.63	43.08	12.60
Linatex Overflow	1.37	6.05	2.15
Linatex Underflow	10.32	4.25	2.50
Derrick Screen Underflow	2.72	12.53	3.97

Froth Flotation

	% Solids	% Ash	% Sulphur
Feed	1.62	9.01	3.12
Product from Cell 1	20.62	3.30	2.05
Product from Cell 2	14.20	4.65	2.32
Tailings	0.16	35.09	5.01

Dewatering Circuit

	% Solids	% Ash	% Sulphur
Thickener Feed	0.64	24.05	3.45
Thickener Overflow	0.01	NA	NA
Thickener Underflow	3.21	29.24	5.37
Clean Coal Centrifuge Effluent	7.60	4.55	2.12
Fine Reject Centrifuge Effluent	1.57	34.59	3.21

Note: Ash, Sulphur and Mass are reported on a dry basis.

Table 14 - Analysis of products from different circuits -Test 9

Feed and Products

	% Moisture	% Ash	% Sulphur	Specific Energy (MJ/kg)	Recovery Mass (t)	%
Feed	3.42	5.35	3.19	33.03	5.61	100.0
Clean Coal	7.37	1.85	1.74	34.54	2.81	64.0
Coarse Rejects	32.91	13.68	5.46	29.45	2.55	32.0
Fine Rejects	17.35	24.14	7.22	24.95	0.25	4.0

Coarse Cleaning (Dense Medium Cyclone)

	% Solids	% Ash	% Sulphur
Deslime Screen Overflow	69.80	5.37	3.24
Clean Coal	64.97	1.31	1.60
Rejects	67.09	13.68	5.46

Compound Water Only Cyclone Circuit

	% Solids	% Ash	% Sulphur
Deslime Screen Underflow	3.52	6.41	2.65
CWC OU (Clean Coal)	27.37	3.10	2.23
CWC UU (Rejects)	5.66	44.66	12.19
Linatex Overflow	1.45	7.29	2.45
Linatex Underflow	12.33	4.29	2.49
Derrick Screen Underflow	3.20	11.88	3.88

Froth Flotation

	% Solids	% Ash	% Sulphur
Feed	1.73	9.12	3.11
Product from Cell 1	21.37	3.78	2.29
Product from Cell 2	11.96	4.71	2.43
Tailings	0.34	21.83	3.82

Dewatering Circuit

	% Solids	% Ash	% Sulphur
Thickener Feed	0.63	18.56	3.50
Thickener Overflow	0.04	28.97	3.88
Thickener Underflow	2.56	20.21	3.55
Clean Coal Centrifuge Effluent	8.10	4.44	2.21
Fine Reject Centrifuge Effluent	1.18	24.42	3.50

Table 15 - Summary of pilot plant results of samples prepared for combustion testing

Test No.	Raw Feed		Clean Coal		Reject (Coarse & Fine)		Yield	Thermal Recovery	Sulphur Removal
	Ash %	S %	Ash %	S %	Ash %	S %	%	%	%
2	6.76	3.45	3.27	2.49	49.15	15.96	91.57	95.80	33.90
7	5.35	3.21	2.04	1.96	19.90	7.61	65.43	68.24	60.05
9	5.35	3.19	1.85	1.74	14.61	5.62	64.00	66.93	65.09

Table 16 - Heavy Medium Cyclone and Batac jig performance

	Heavy Medium Cyclone		Batac Jig
	Test 7	Test 9	Test 2
Feed size (mm)	10 x 0.6	10 x 0.6	10 x 0.6
Feed ash - sulphur (%)	5.47-2.91	5.05-3.12	5.60-3.33
Clean coal ash - sulphur (%)	1.79-1.91	1.16-1.57	2.98-2.40
Refuse ash - sulphur (%)	20.23-8.37	11.09-4.64	44.10-12.78
Yield of clean coal (%)	80.04	60.83	93.63
Theoretical yield (%)	86.11	67.07	94.08
Organic efficiency (%)	92.95	90.70	99.52
Thermal recovery (%)	83.88	63.90	96.83
Ash removal (%)	73.81	86.03	49.82
Sulphur Removal (%)	47.46	69.39	32.35
+/- Near density material (%)	-----	-----	1.39
Floats in refuse (%)	31.88	40.78	26.84
Sinks in clean coal (%)	2.99	13.27	0.70
Total misplaced material (%)	8.76	24.05	2.37
Yield error	6.07	6.24	0.45
Ash error	-0.26	-0.40	-0.13
Relative density of separation (dp)	1.33	1.28	1.73
Probable error (Ep)	0.03	0.03	0.20
Error area	22	20	

Table 17 - Water-Only Tricone Cyclone performance (fines).

	Tricon Cyclone (CWC)
Feed size (mm)	0.6 x 0.15
Feed ash - sulphur (%)	4.02-2.50
Clean coal ash - sulphur (%)	2.48-2.05
Refuse ash - sulphur (%)	45.16-12.28
Yield of clean coal (%)	96.39
Theoretical yield (%)	98.51
Organic efficiency (%)	98.29
Thermal recovery (%)	98.27
Ash removal (%)	40.53
Sulphur Removal (%)	20.96
+/- Near density material (%)	0.13
Floats in refuse (%)	44.47
Sinks in clean coal (%)	0.21
Total misplaced material (%)	1.80
Yield error	2.12
Ash error	-0.16
Relative density of separation (dp)	2.03
Probable error (Ep)	0.27
Error area	132

Table 18 - Froth flotation performance - Test 7

Coal size (mm)	0.15 x 0
Feed rate (tph)	0.44
Retention time (seconds)	180
Reagent Dosage (kg/tonne)	0.13
Ratio MIBC : Kerosene	1:5
Feed Ash - Sulphur %	9.01 - 3.12
Clean Coal Ash - Sulphur %	3.35 - 2.20
Tailings Ash - Sulphur %	35.4 - 5.01
Yield %	82.5
Thermal recovery %	90.0
Ash removal %	69.3
Sulphur removal %	41.8
Efficiency index (ash)	884

Table 19 - Parameters for flowsheet selection.

Option	Thermal Recovery	Sulphur Removal	Flowsheet Option
1	High (95%)	Low (30-35%)	Two products separation, water-only systems (jig + cyclones) for coarse (+0.5mm) and fines (0.5 x 0.15 mm) and froth flotation for 0.15 mm x 0.
2	Low (60-80%)	High (60-70%)	Two product separation, heavy medium cyclone for coarse (+0.5 mm), water-only cyclones for fines (0.5 x 0.15 mm) and froth flotation for 0.15 mm x 0.
3	High* (95%)	High ** (60-66%)	Three product separation, heavy medium cyclone for the primary product, heavy medium cyclone or water-only system for the secondary product, water-only cyclones and froth flotation for the fines (0.5 mm x 0).

* Combined primary and secondary products

** Primary product only

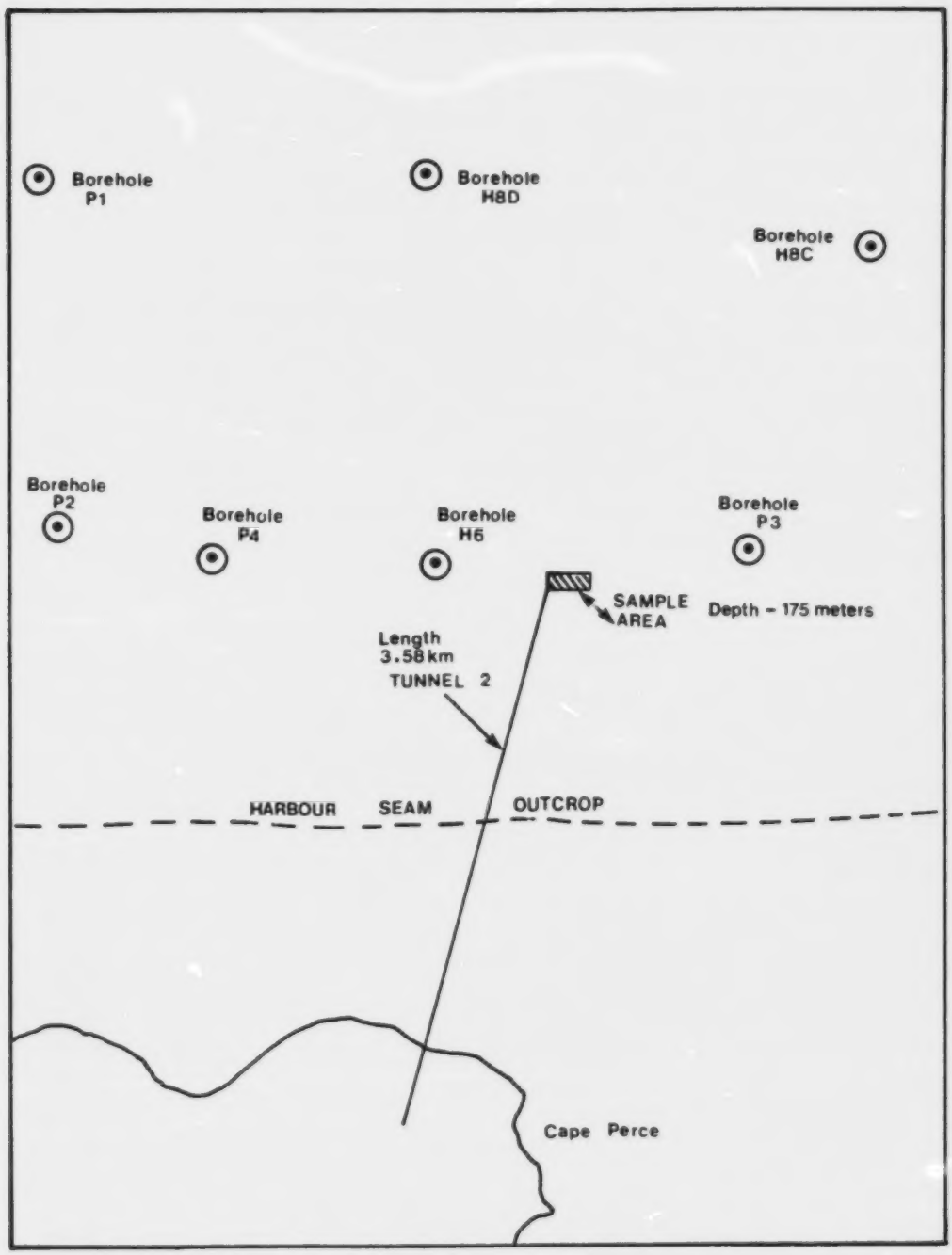


Figure 1 - Sample location - Donkin-Morien tunnel.

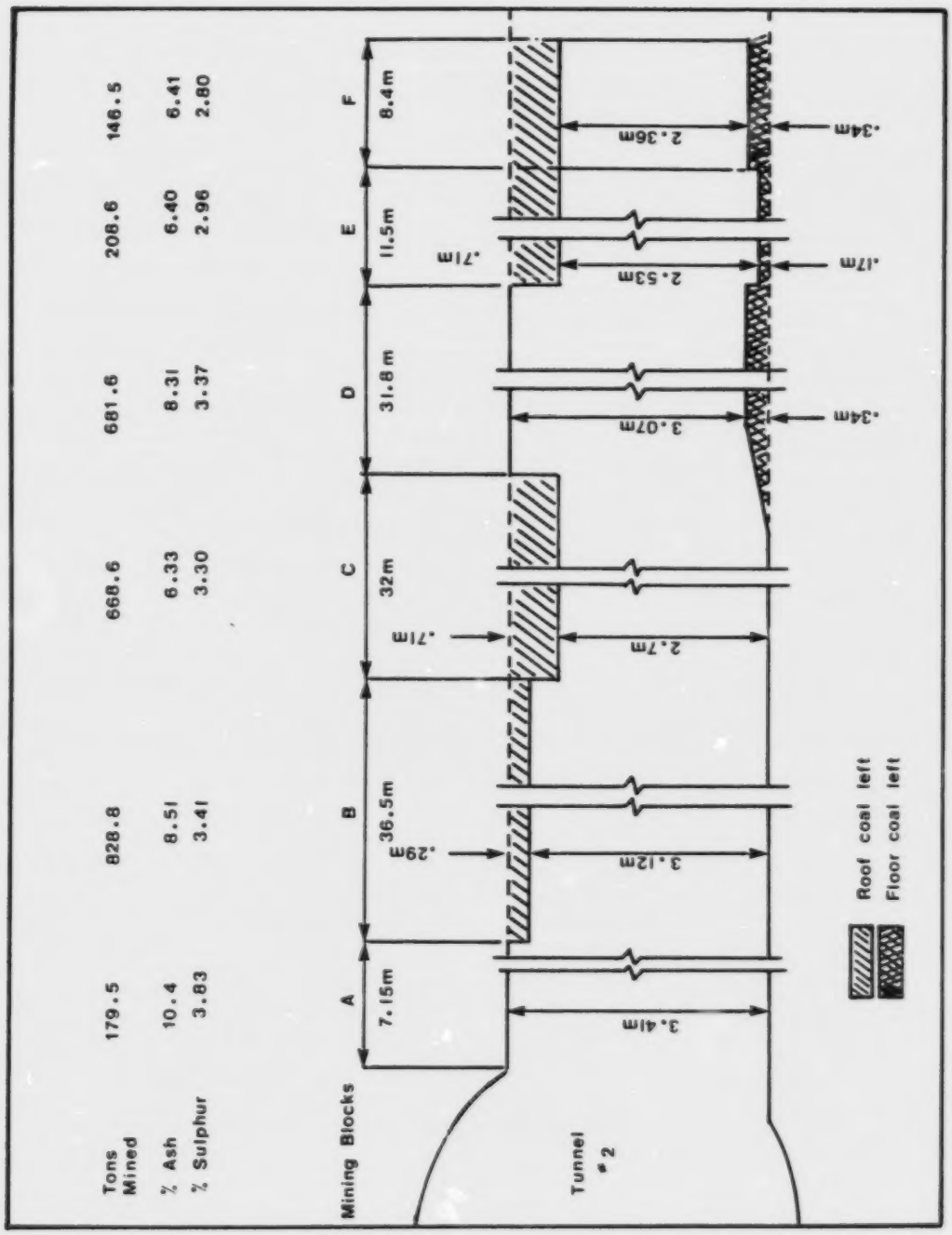


Figure 2 - Sample extraction cross cut - Donkin-Morien

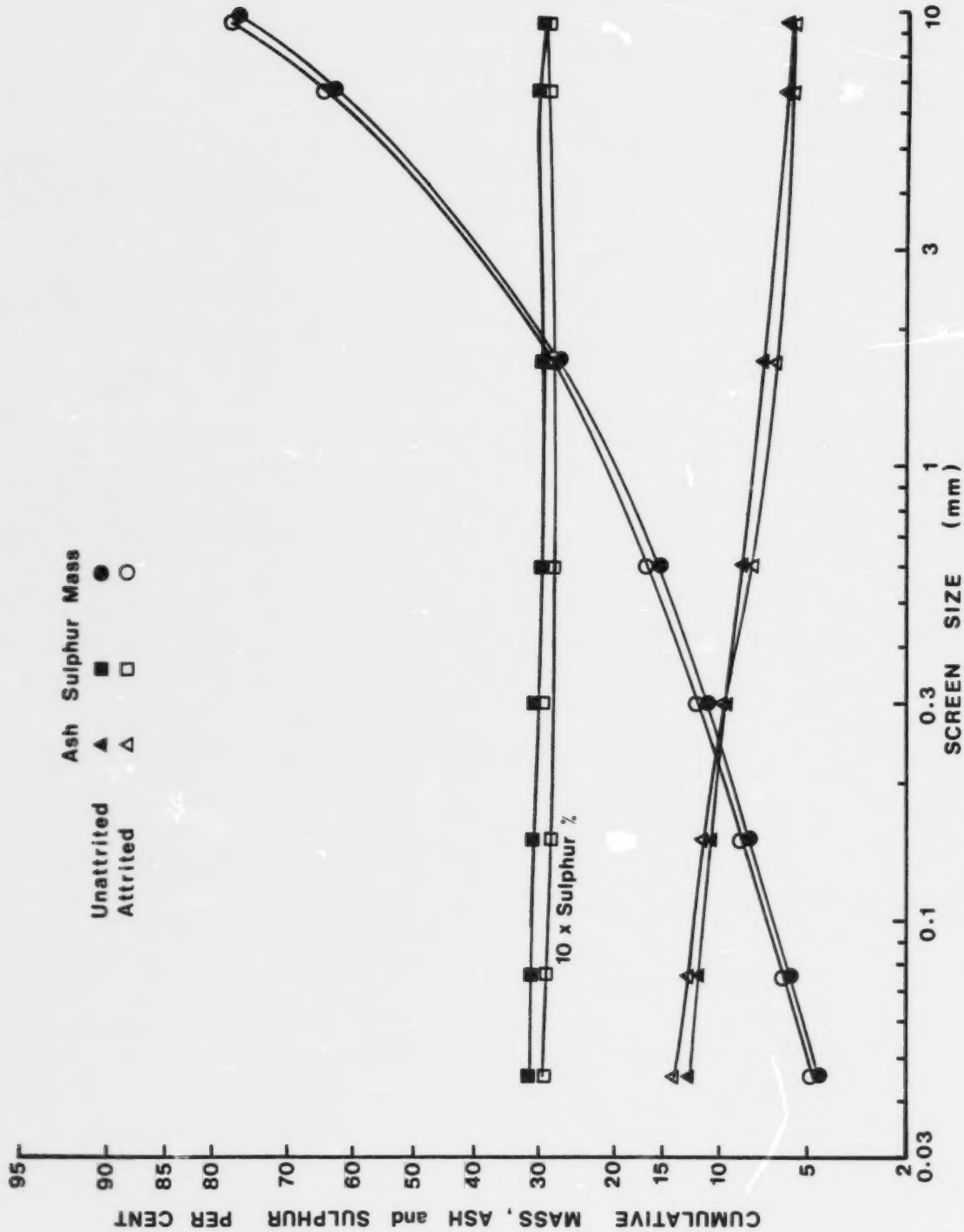


Figure 3 - Size degradation and changes in ash and sulphur contents during wet attrition (50mm X 0).

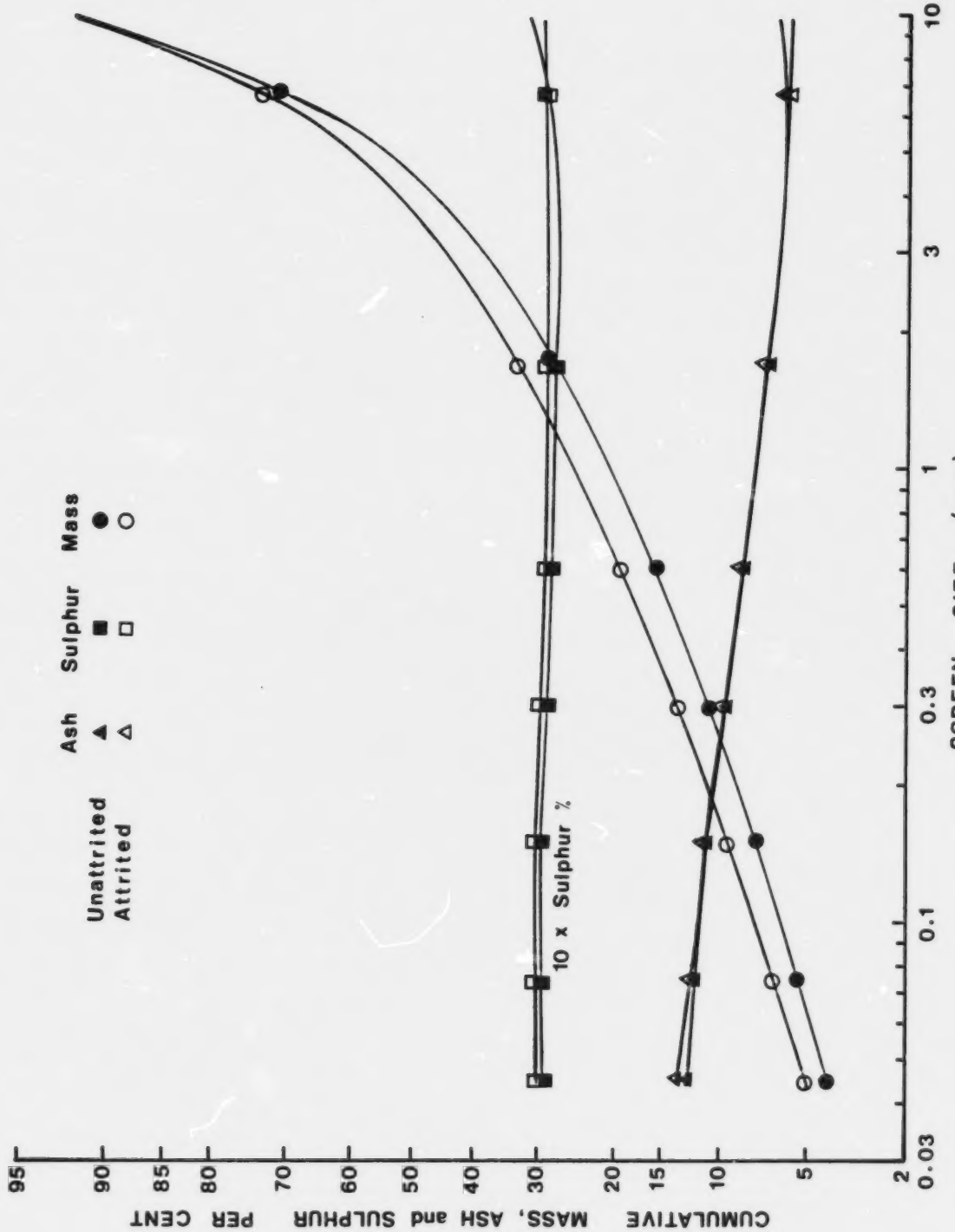


Figure 4 - Size degradation and changes in ash and sulphur contents during wet attrition (10mm X 0)

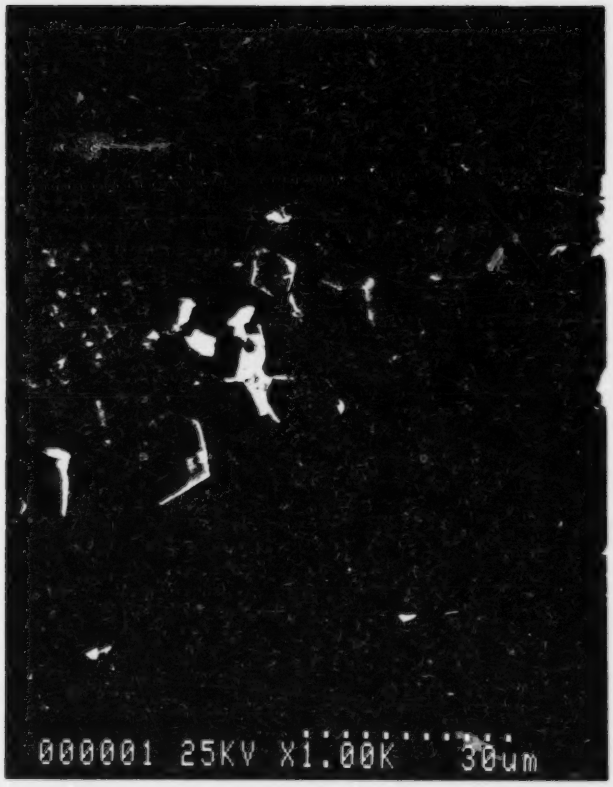


Figure 5a - Pyritic sulphur in coal structure (SEM picture).

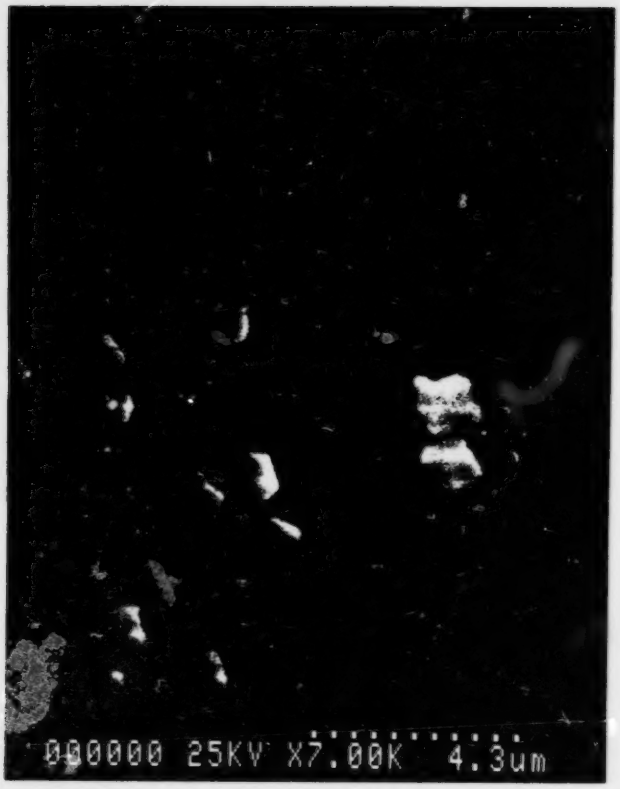


Figure 5b - Pyritic sulphur at high magnification (SEM picture).

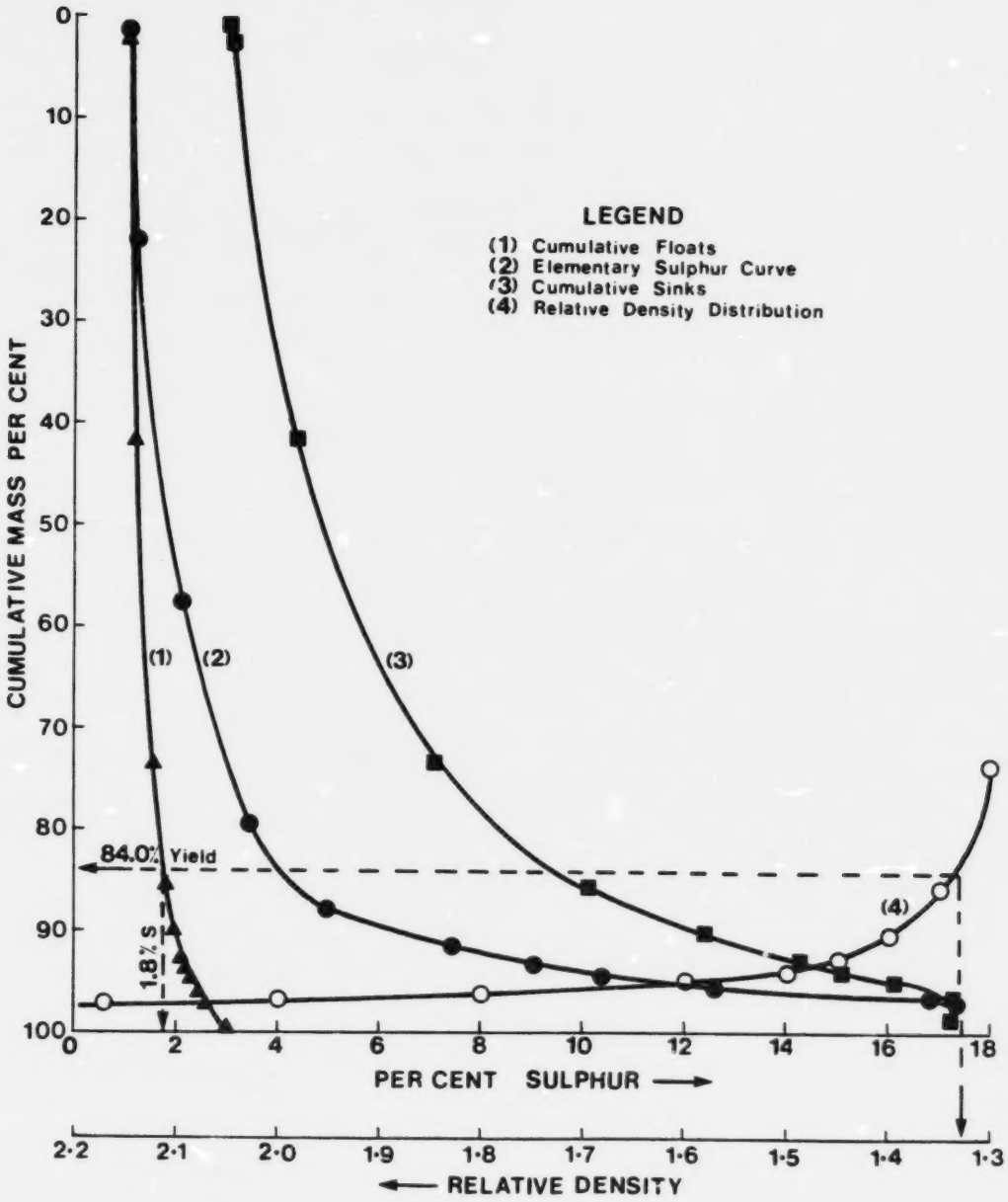


Figure 6 - Donkin-Morien - sulphur washability characteristics (10 X 0.6mm).

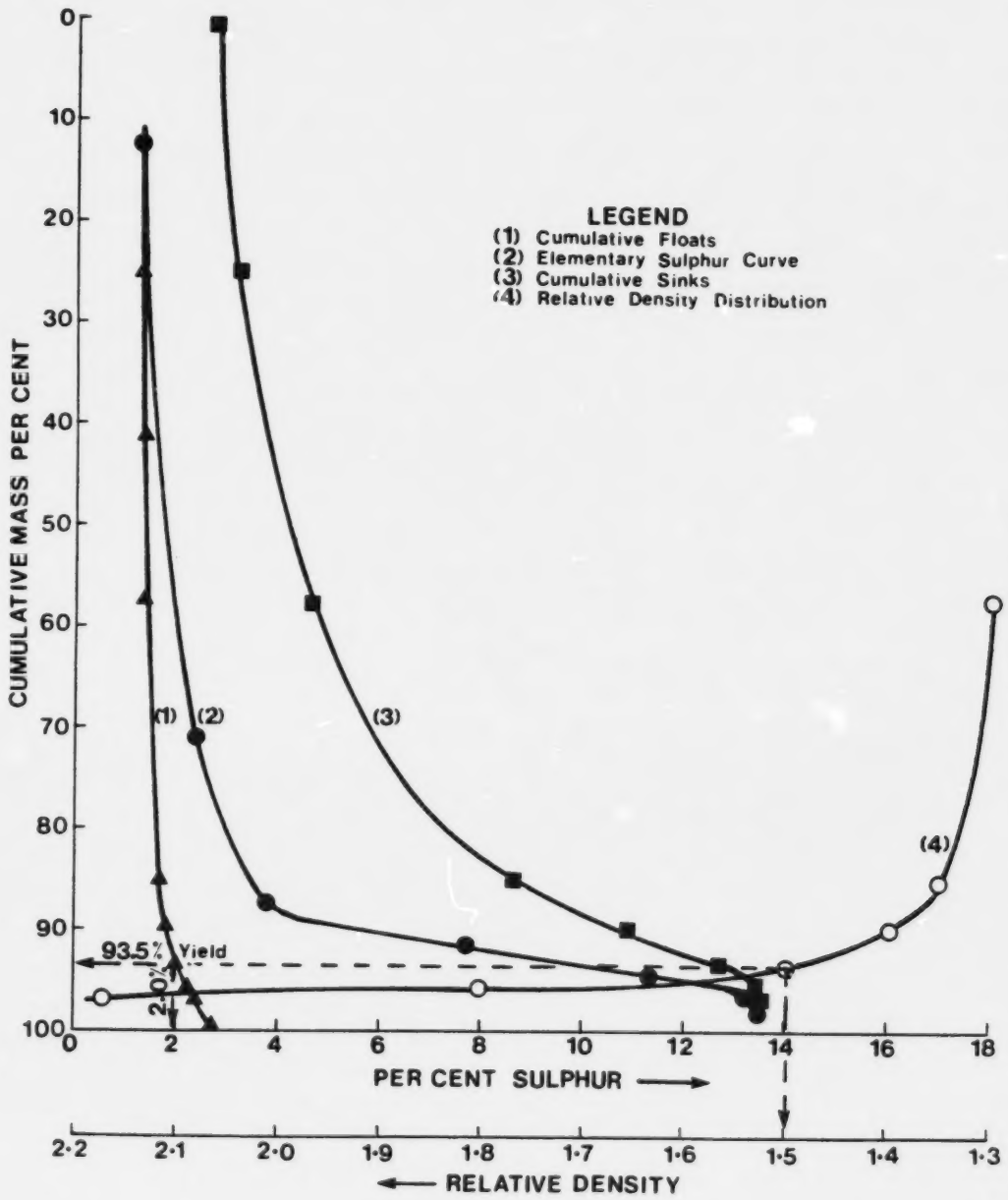


Figure 7 - Donkin-Morien - sulphur washability characteristics (0.6 X 0.15mm).

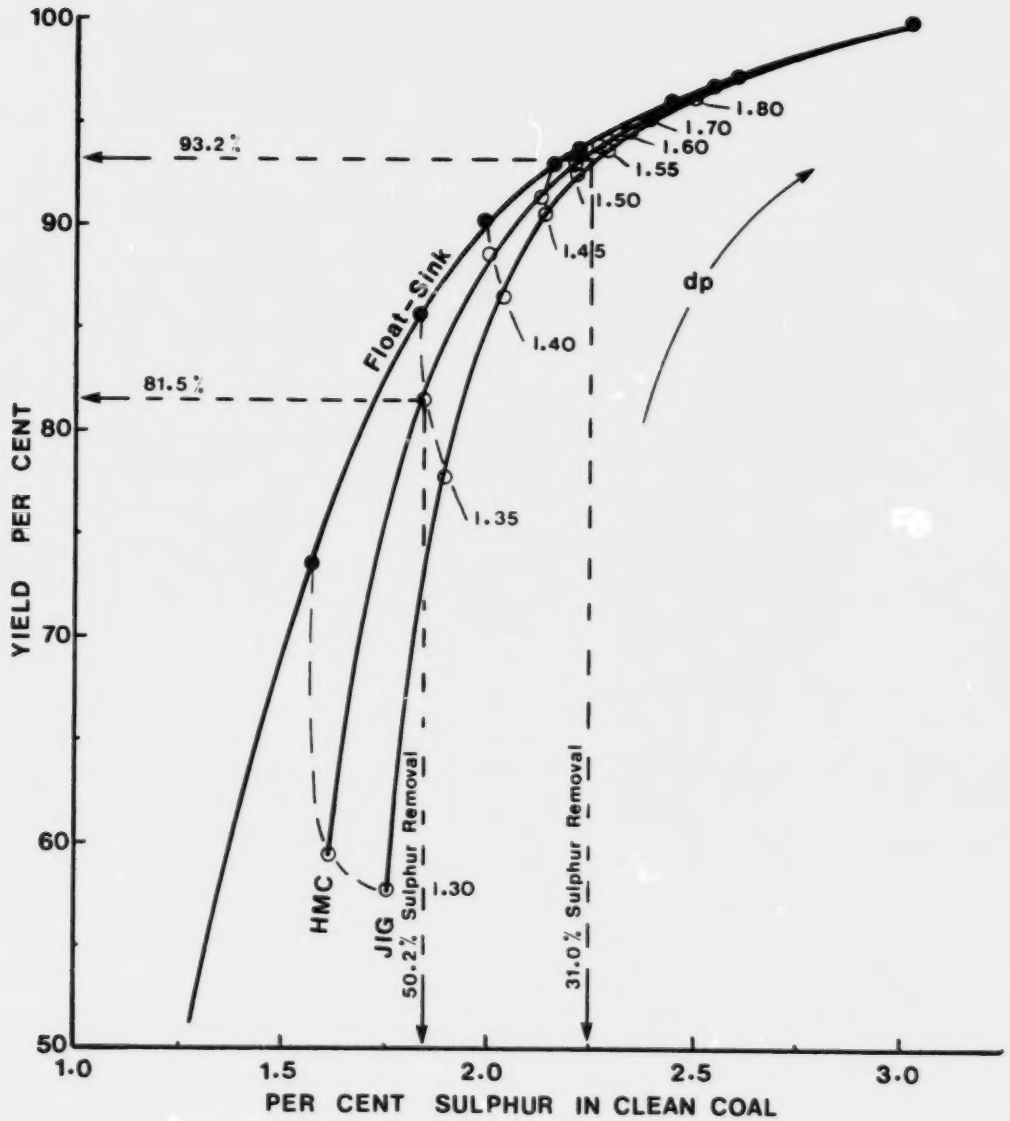


Figure 8 - Performance evaluation prediction (10 X 0.6mm) - sulphur.

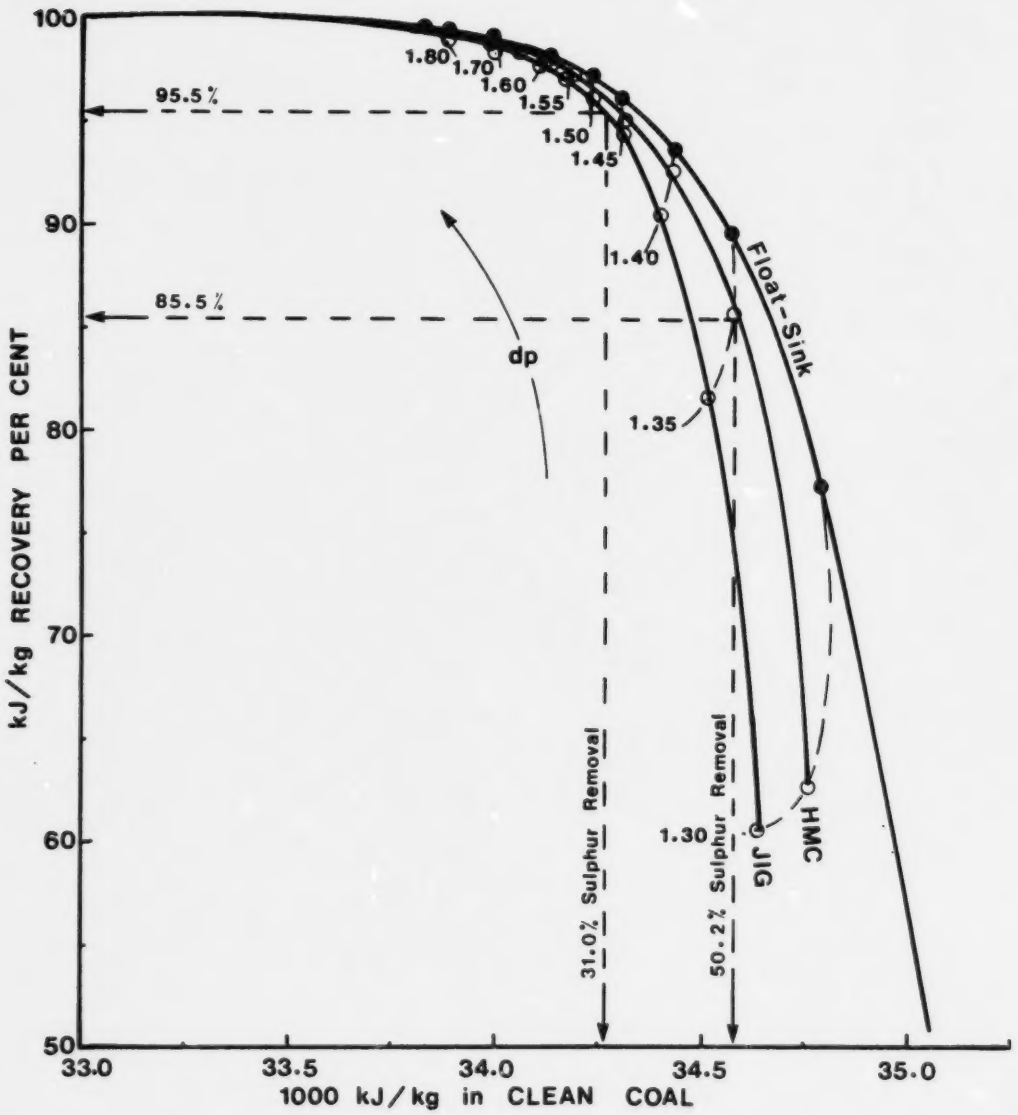


Figure 9 - Performance evaluation prediction (10 X 0.6mm) - thermal recovery.

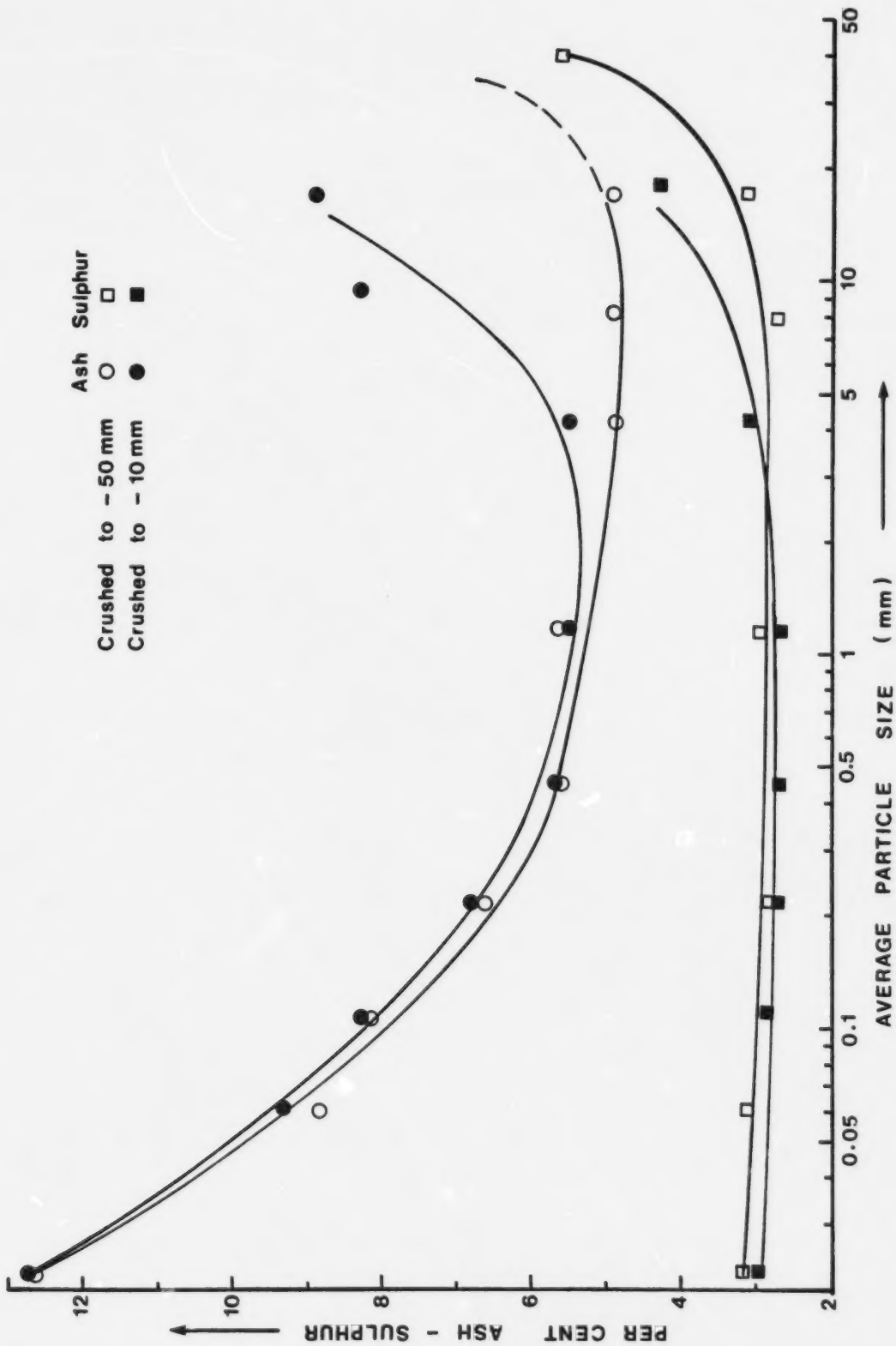


Figure 10 - Effect of crushing on size distribution in relation to ash and sulphur contents.

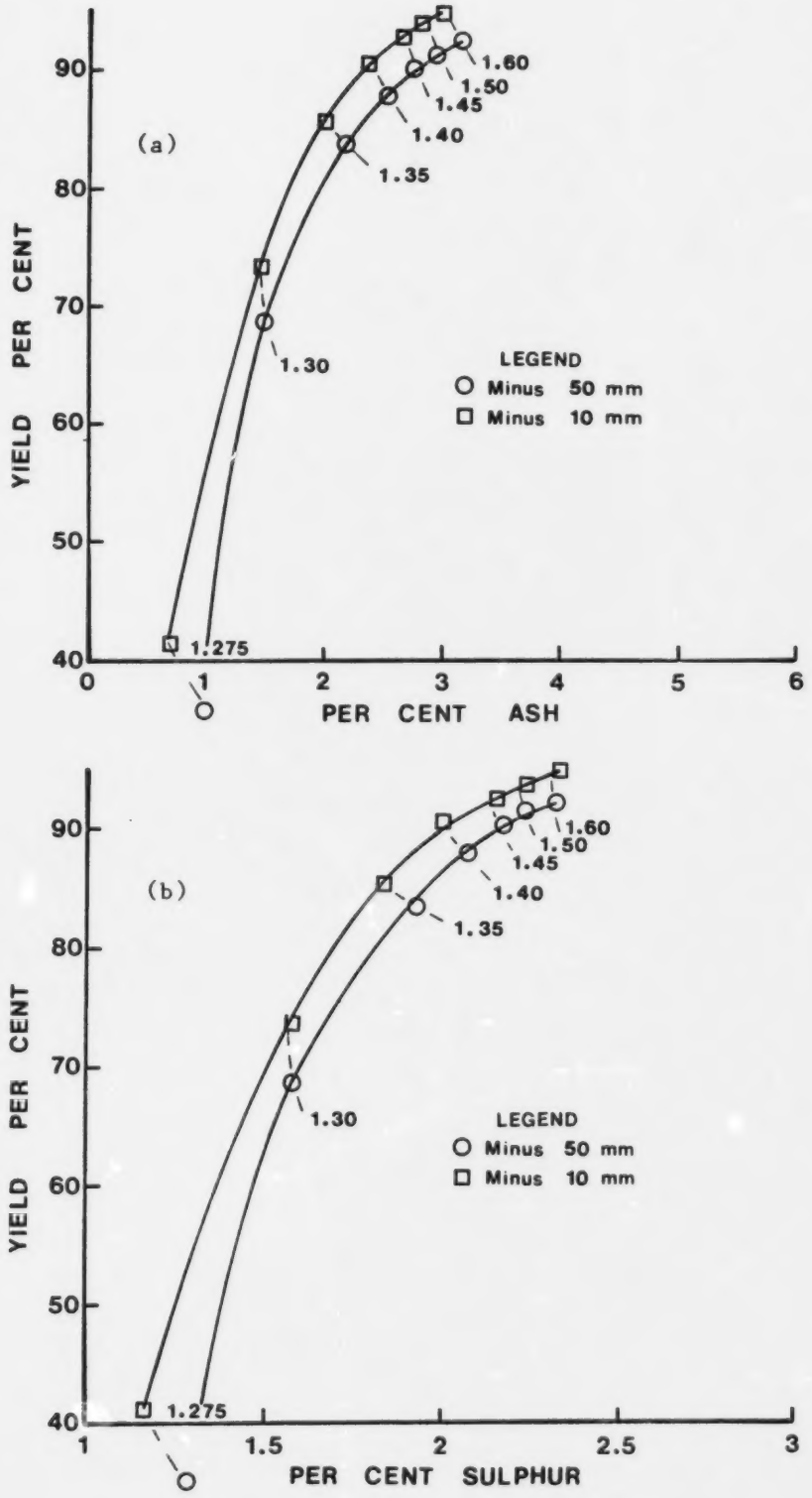


Figure 11 - Effect of crushing on liberation of ash (a) upper and sulphur (b) lower (plus 0.6mm).

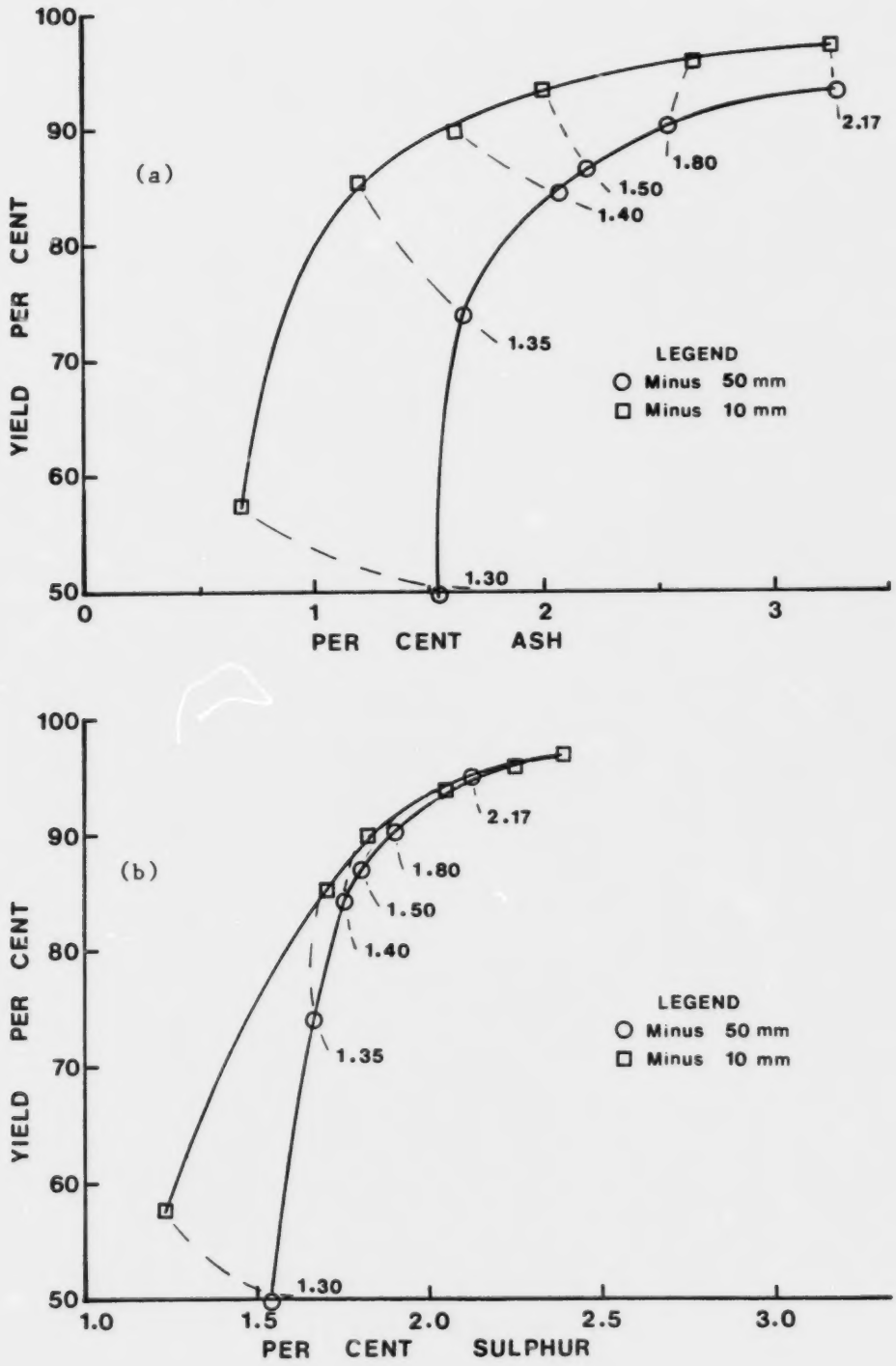


Figure 12 - Effect of crushing on liberation of ash (a) and sulphur (b) (0.6 X 0.15mm).

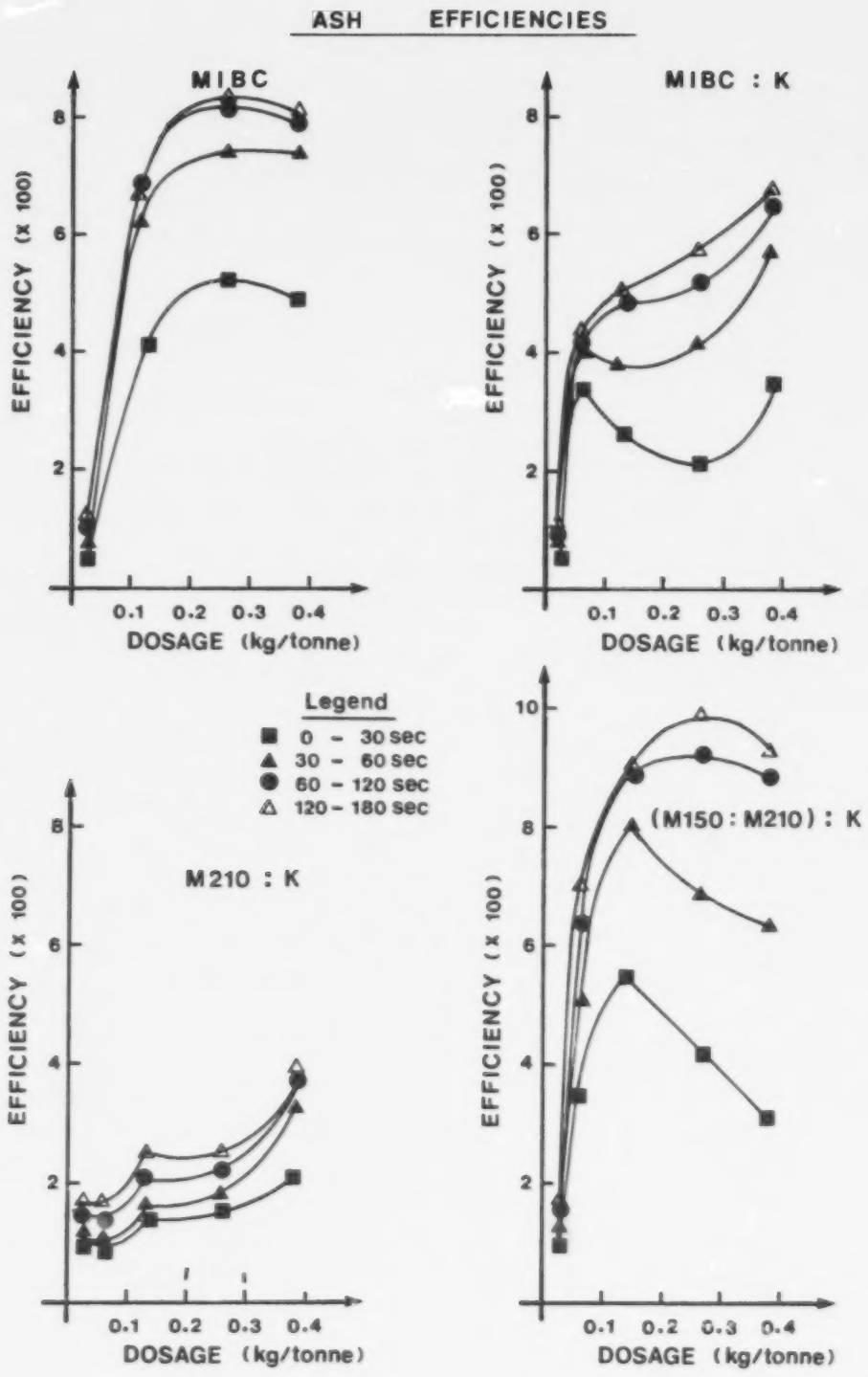


Figure 13 - Flotation ash efficiency in relation to residence time, type and dosage of reagents (0.6mm X 0).

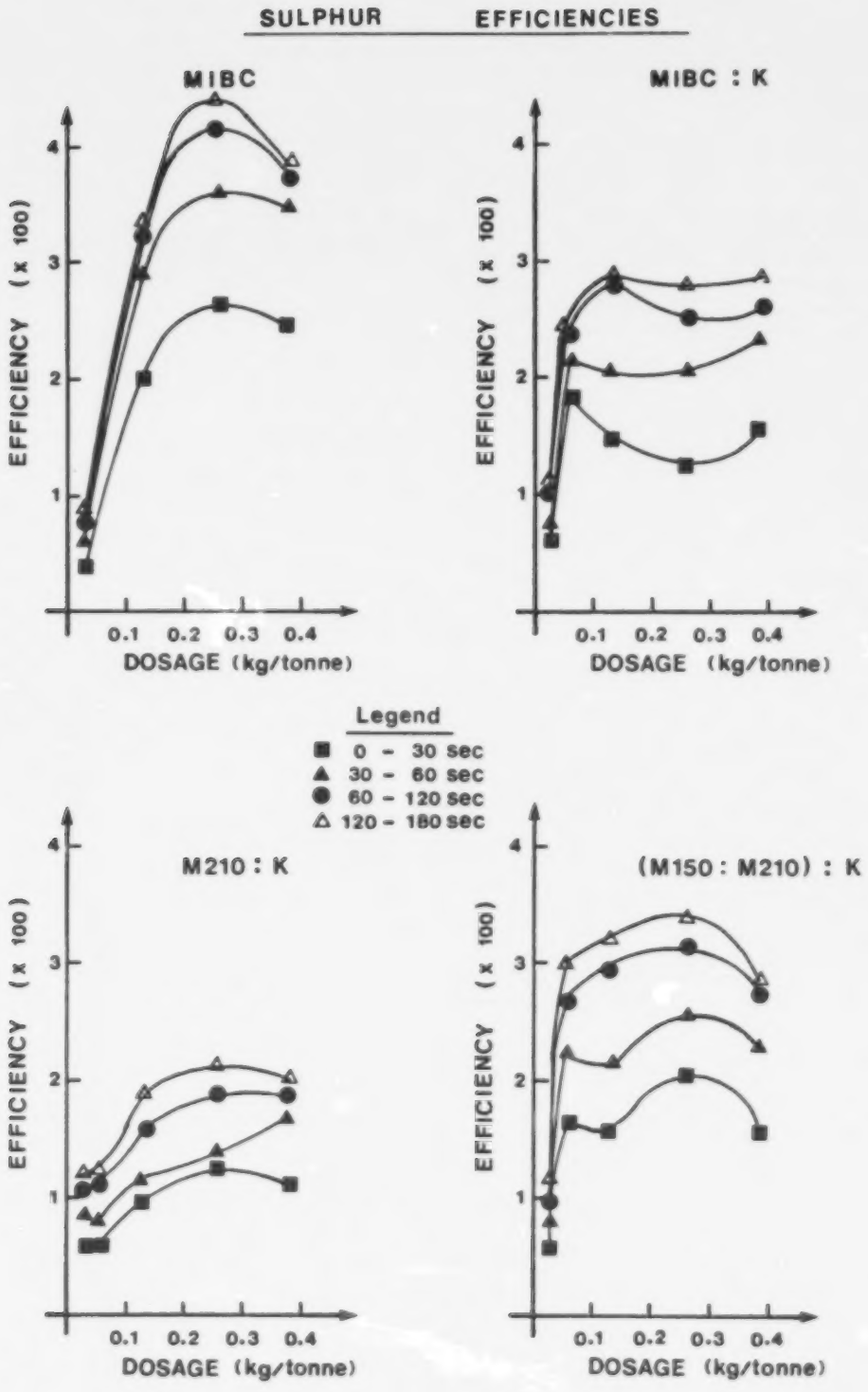


Figure 14 - Flotation sulphur efficiency in relation to residence time, type and dosage of reagents (0.6mm X 0).

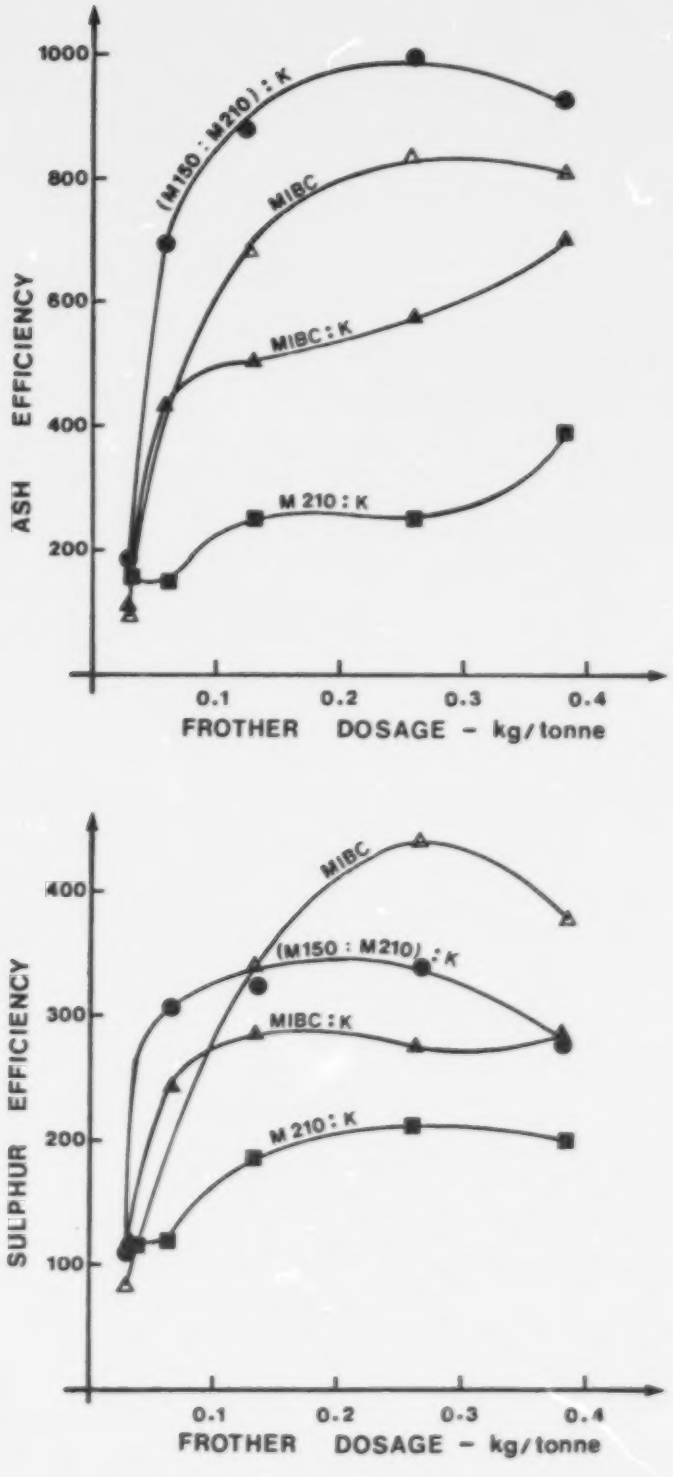


Figure 15 - Flotation efficiencies (ash and sulphur) at 180 seconds residence time.

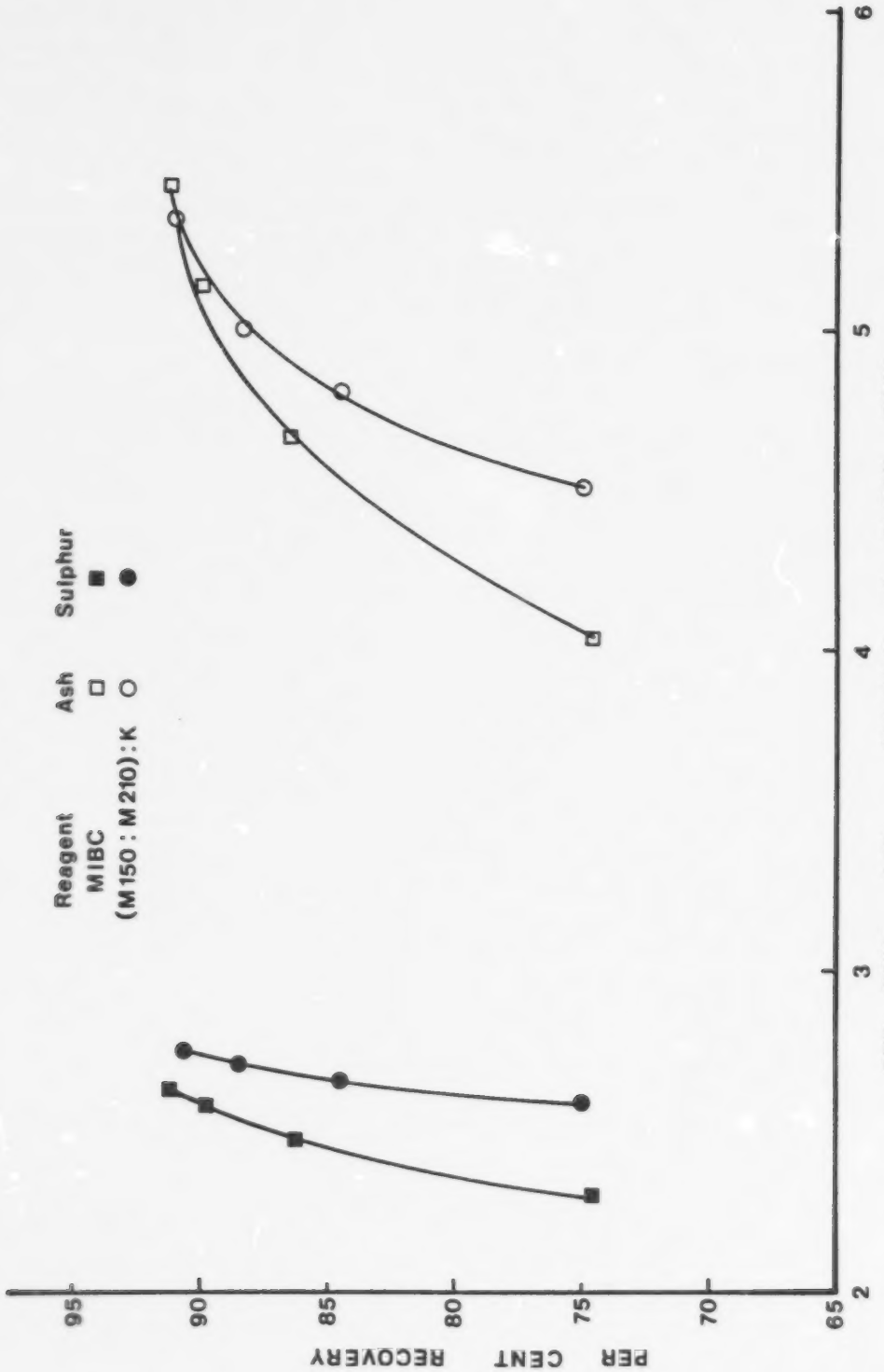


Figure 16 - Ash and sulphur contents of froth flotation clean coal in relation to recovery.

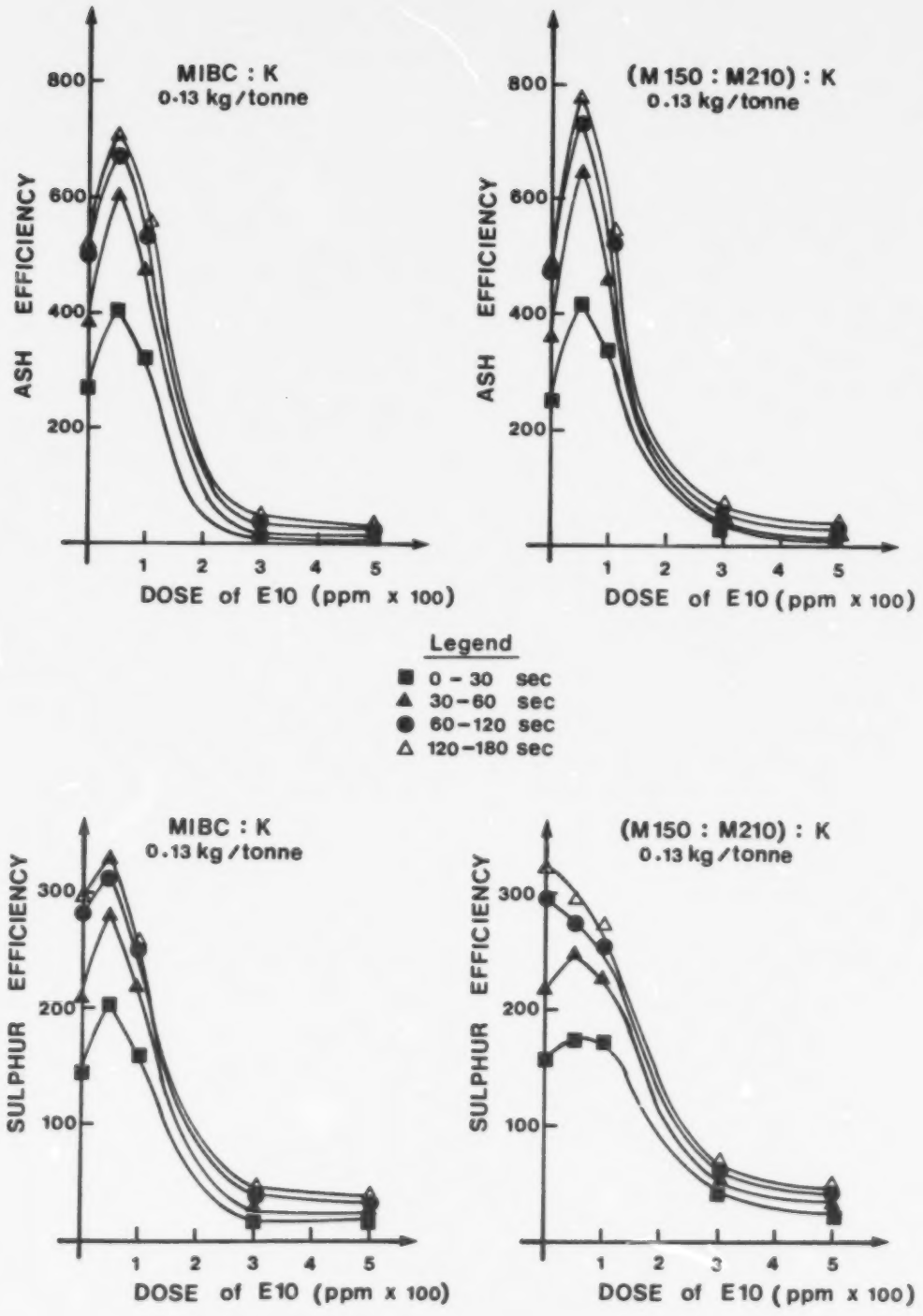


Figure 17- Influence of flocculant (Percol E10) traces in water on flotation efficiency.

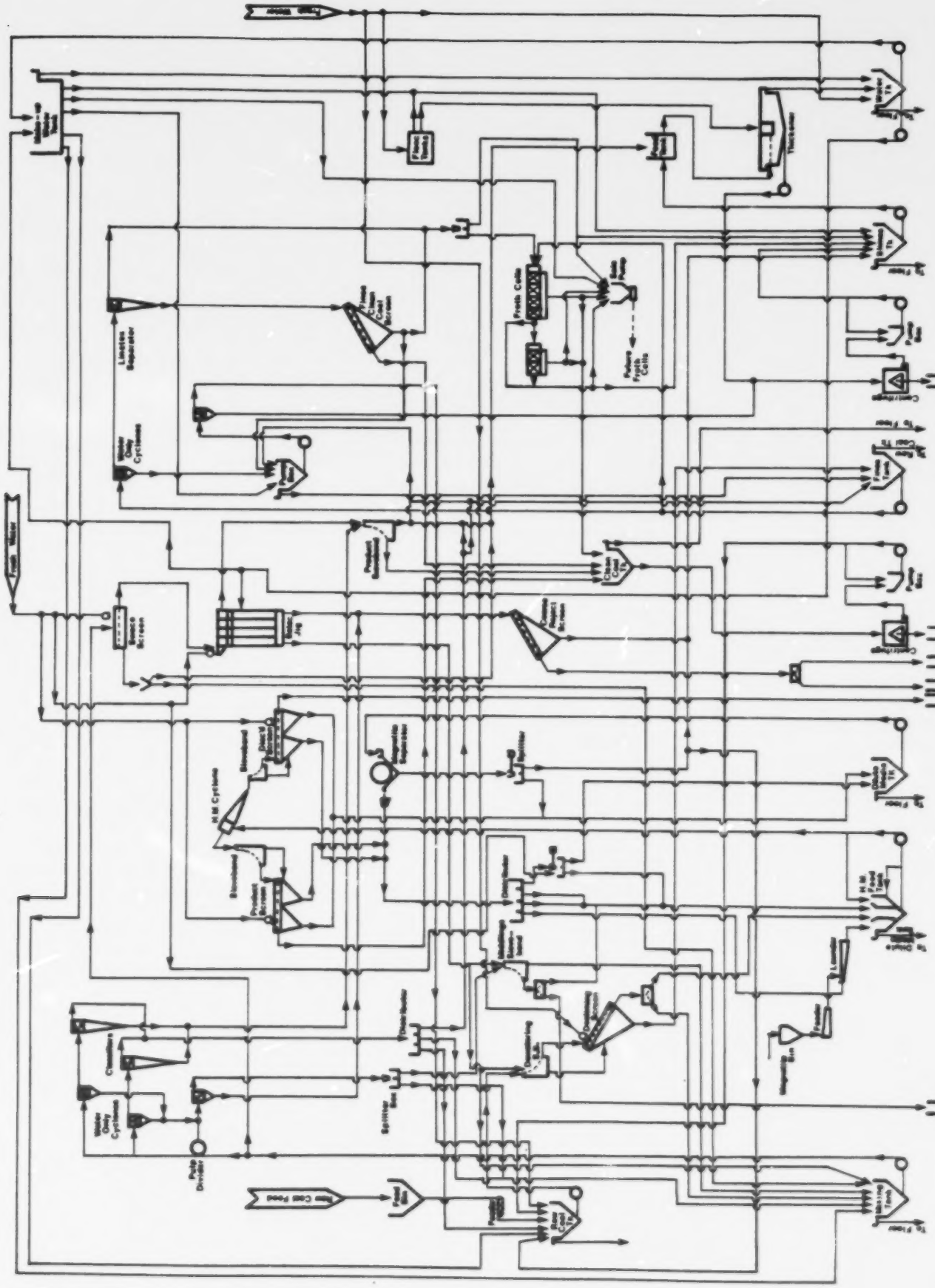


Figure 18 10-TPH COAL PREPARATION PILOT PLANT; CANMET - CRL - DEVON, ALBERTA

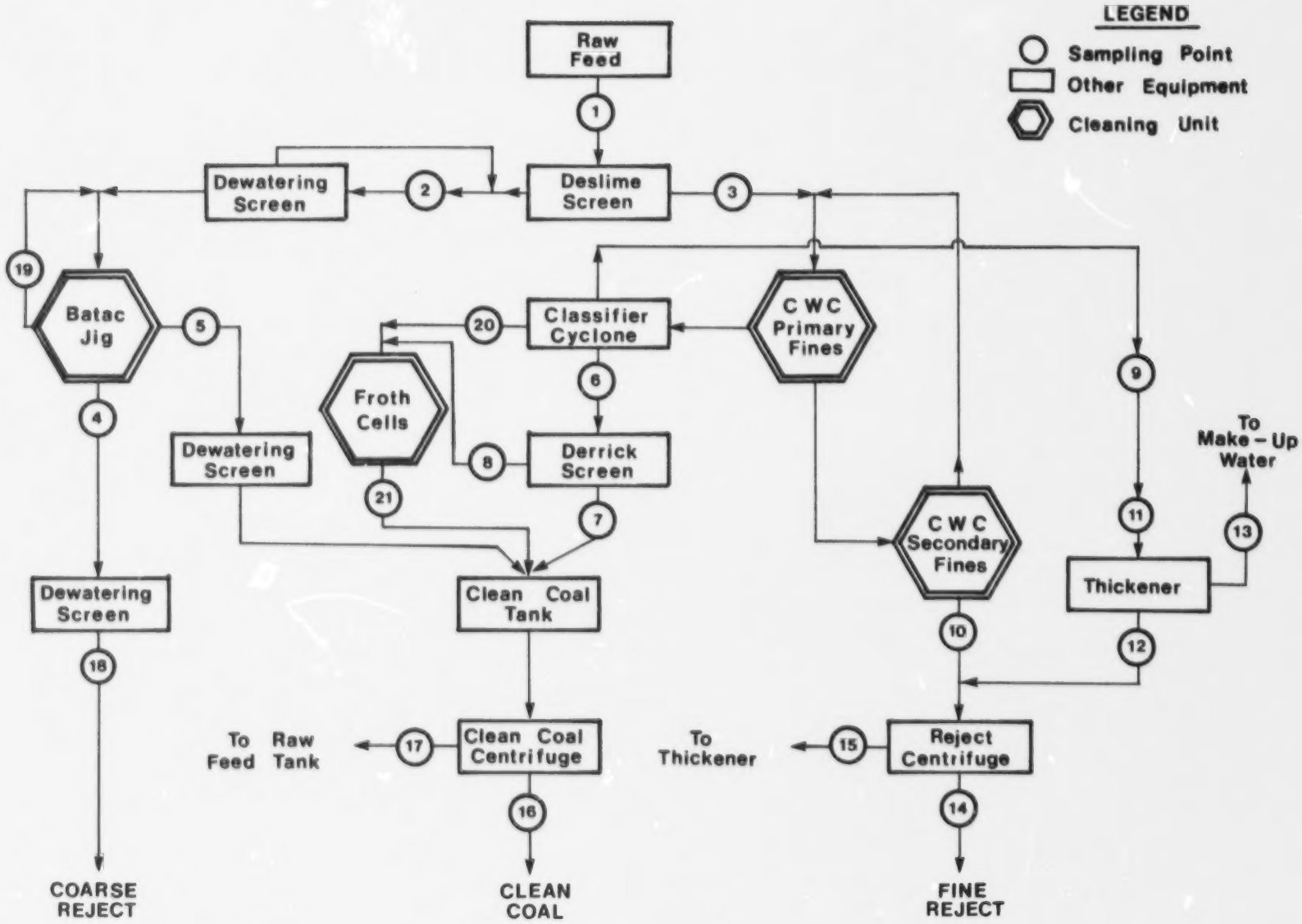


Figure 19 - Batac jig, Water-Only Tricone Cyclone and Froth Flotation simplified flowsheet - Test 2

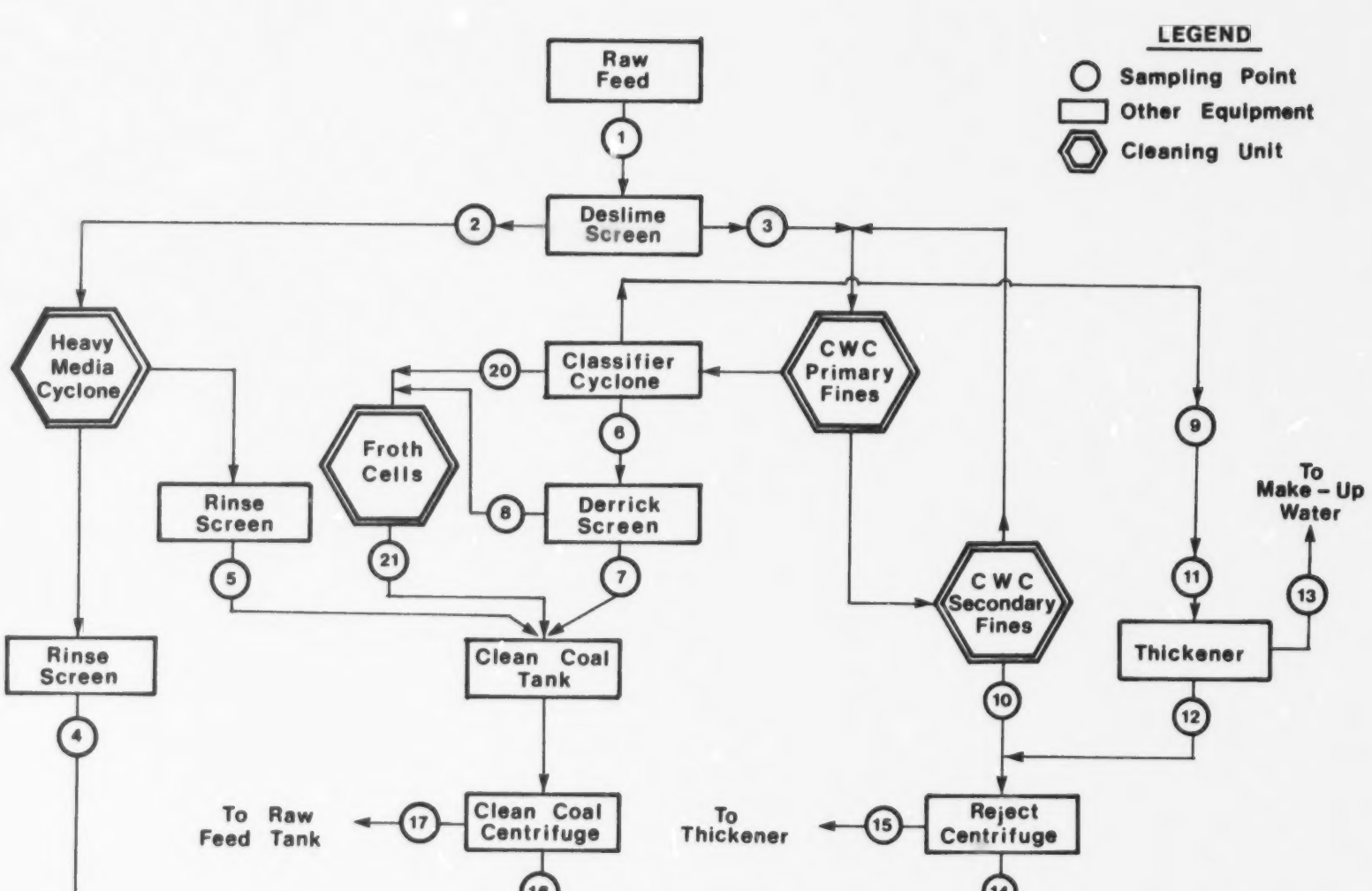
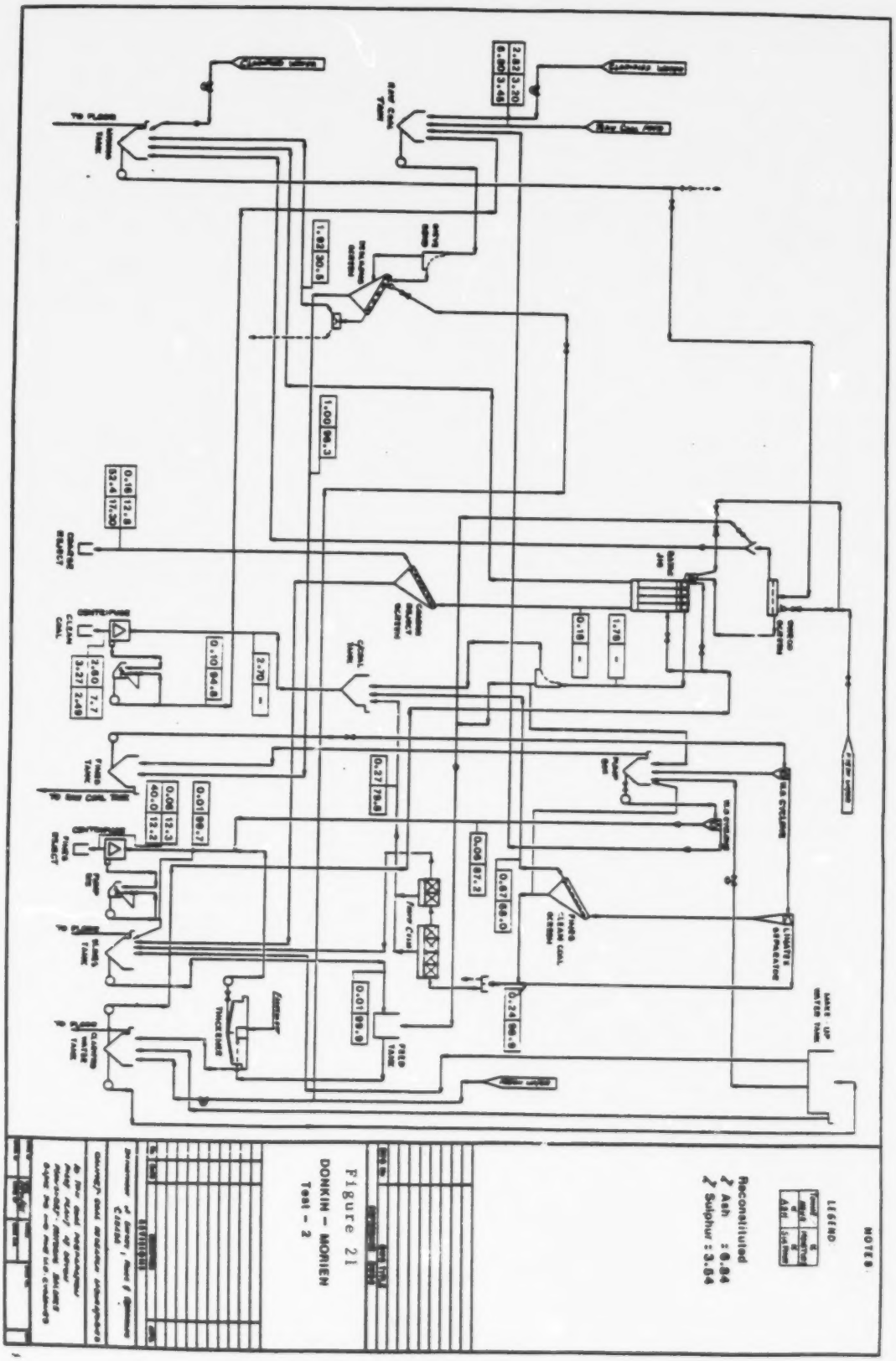
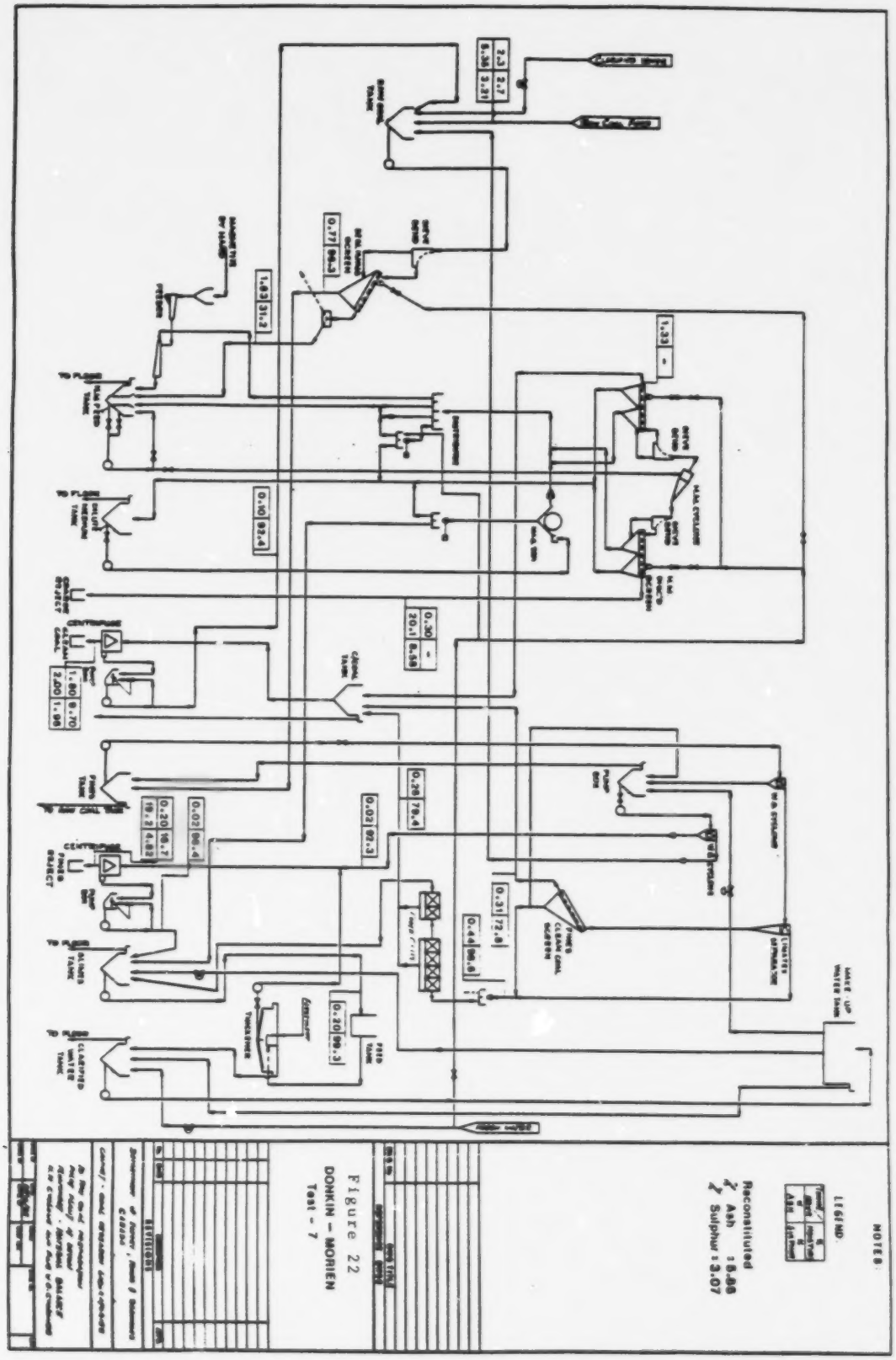
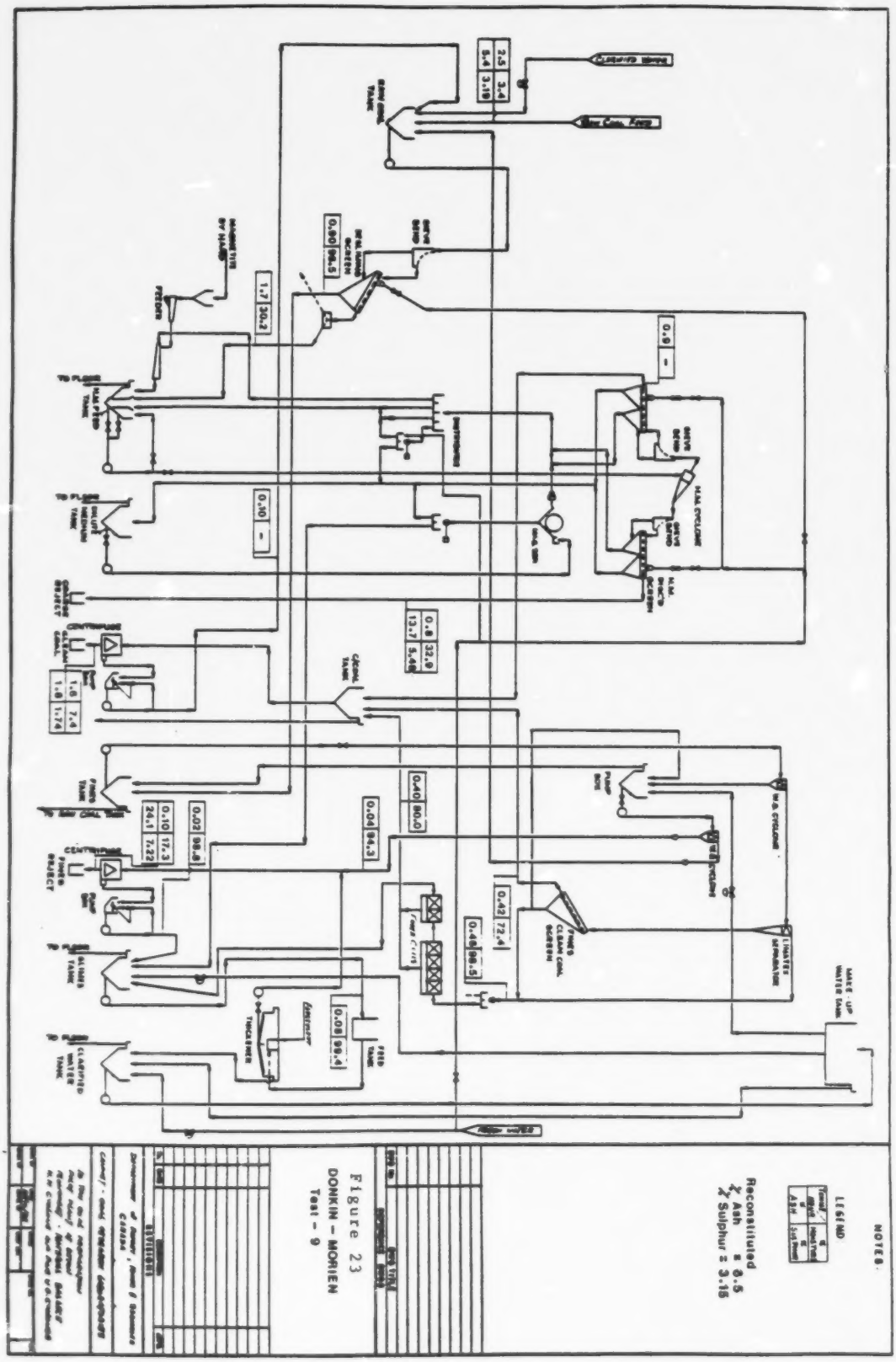


Figure 20 - Heavy Medium Cyclone, Water-Only Tricone Cyclone and Froth Flotation simplified flowsheet - Tests 7 and 9.


NOTES
LEGEND
Reconstituted
Ash : 9.84
Sulphur : 3.84
Figure 21
DONKIN – MORIEN
Test - 2


NOTES
Reconstituted
Ash : 15.00
Sulphur : 3.07
Figure 22
DONKIN – MORIEN
Test - 7


NOTES
LEGEND
Reconstituted
% Ash = 8.5
% Sulphur = 3.15
Figure 23
DONKIN – MORIEN
Test – 9

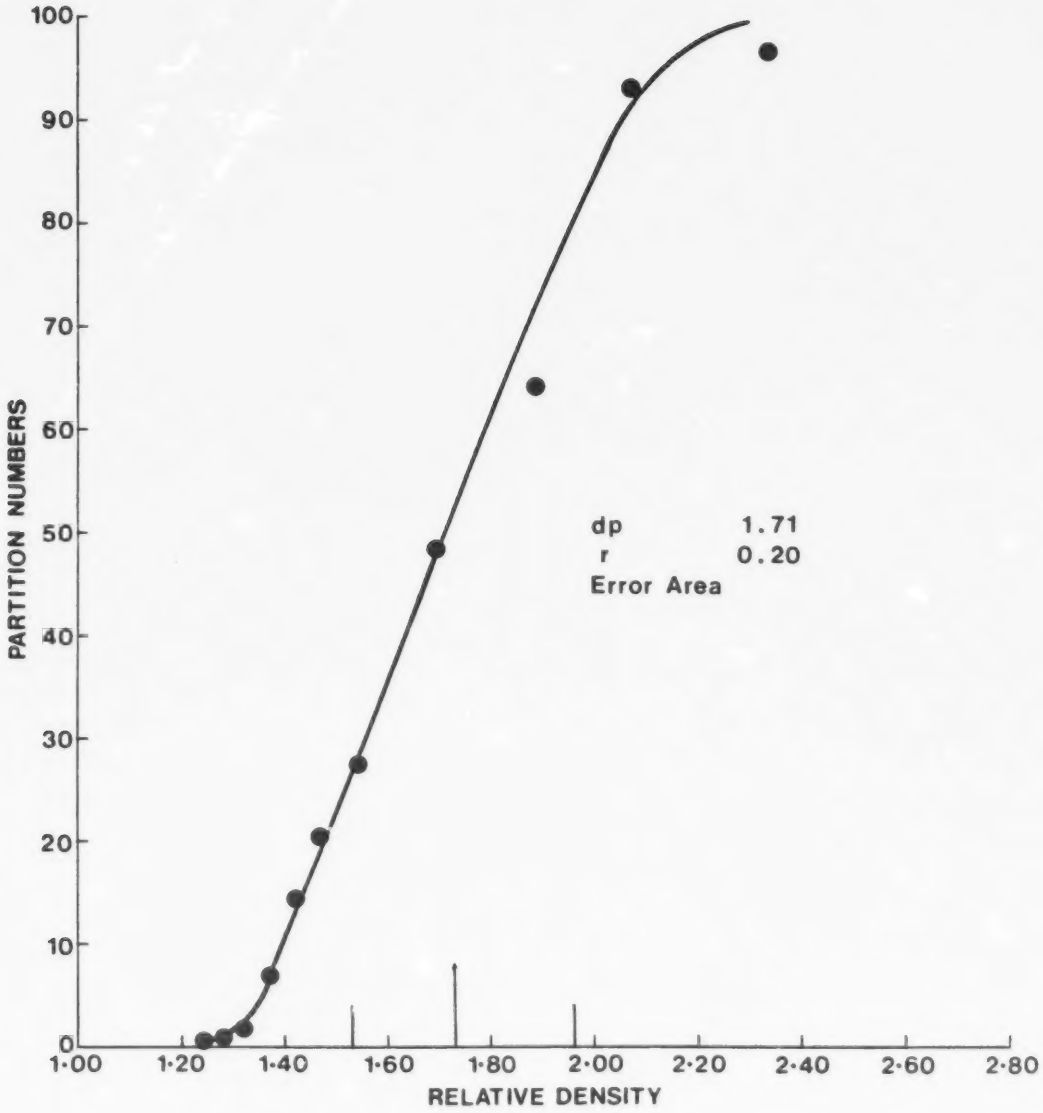


Figure 24 - Batac jig error curve (10 X 0.6mm) - Test 2.

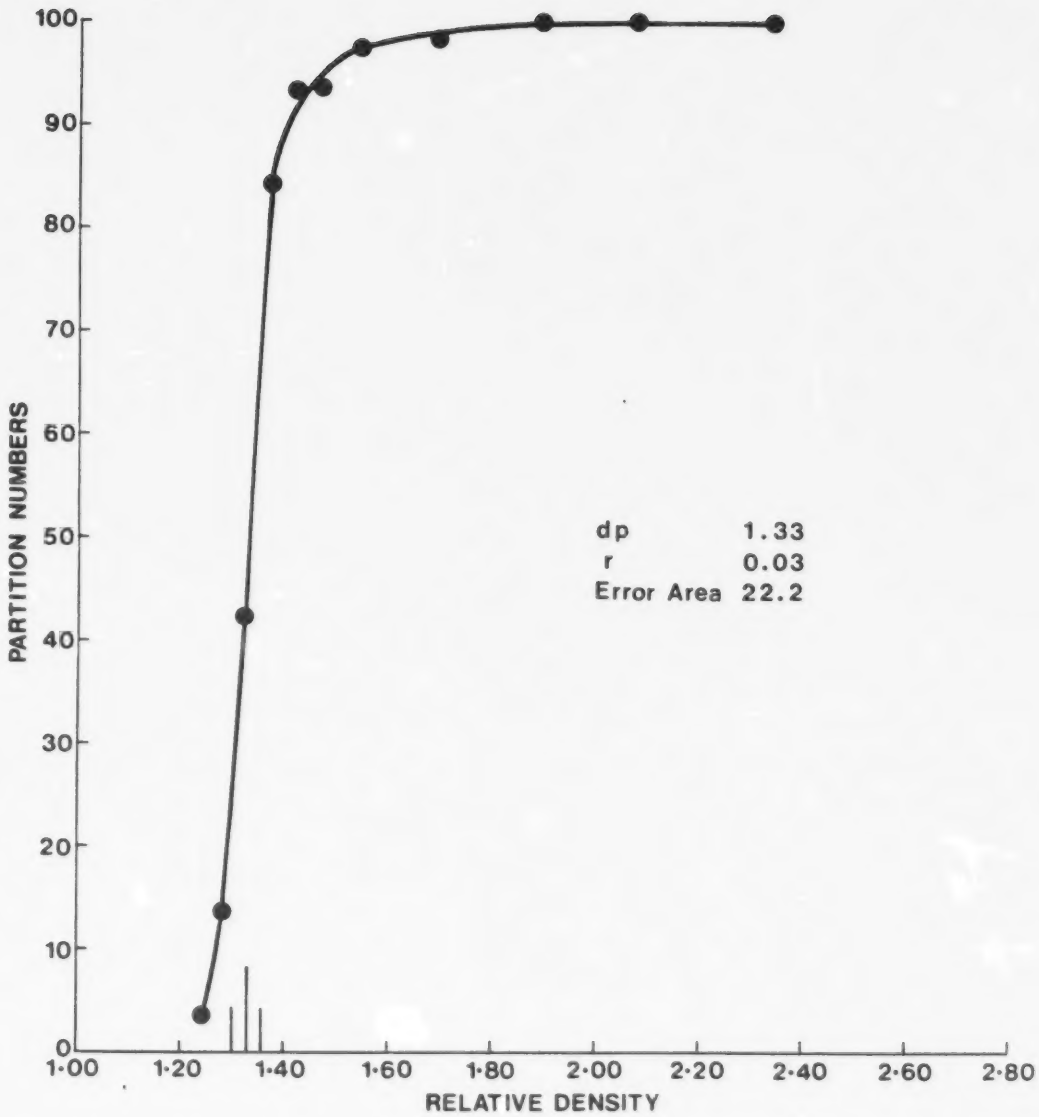


Figure 25 - Heavy Medium Cyclone error curve - Test 7 (10 X 0.6mm)

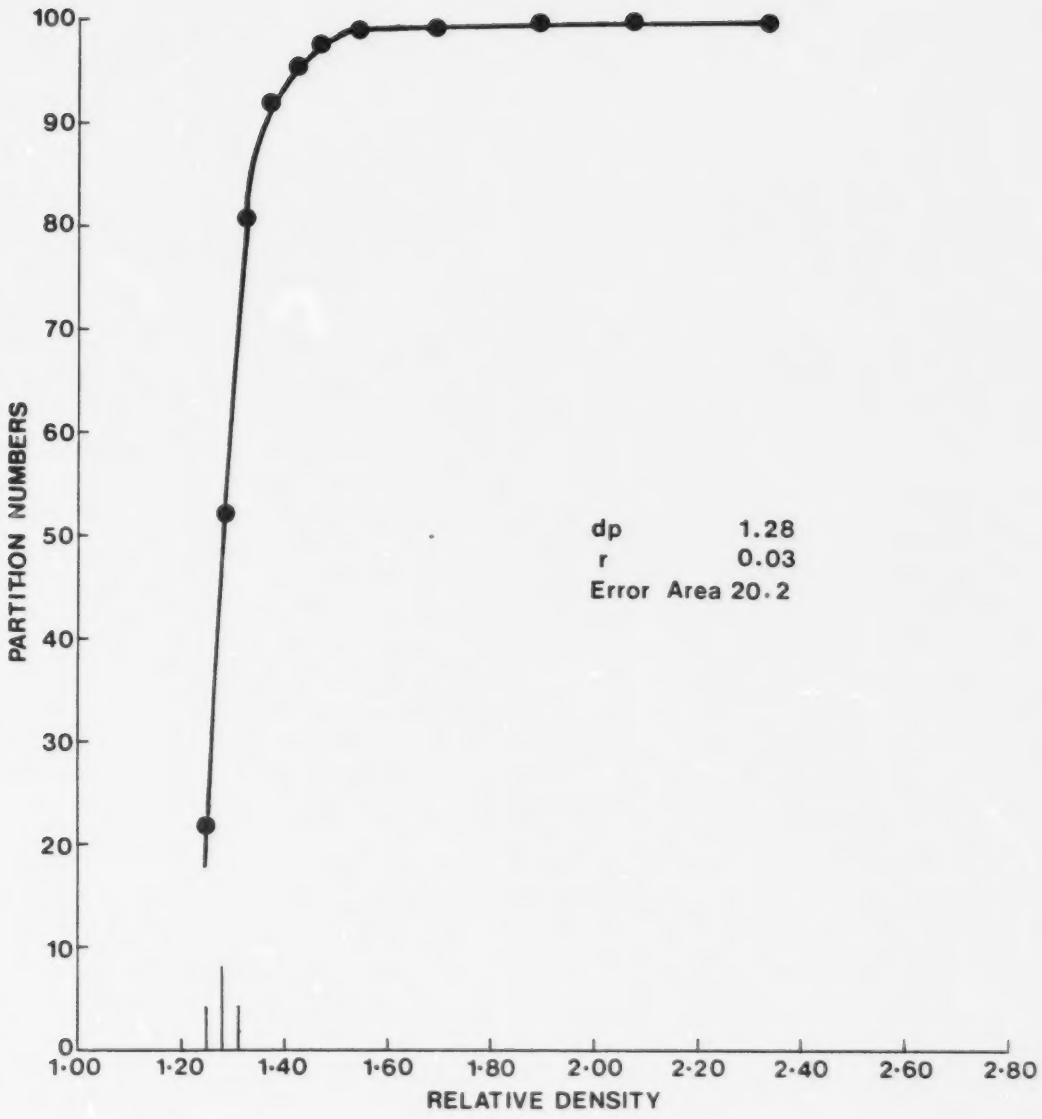


Figure 26 - Heavy Medium Cyclone error curve Test 9 (10 X 0.6mm)

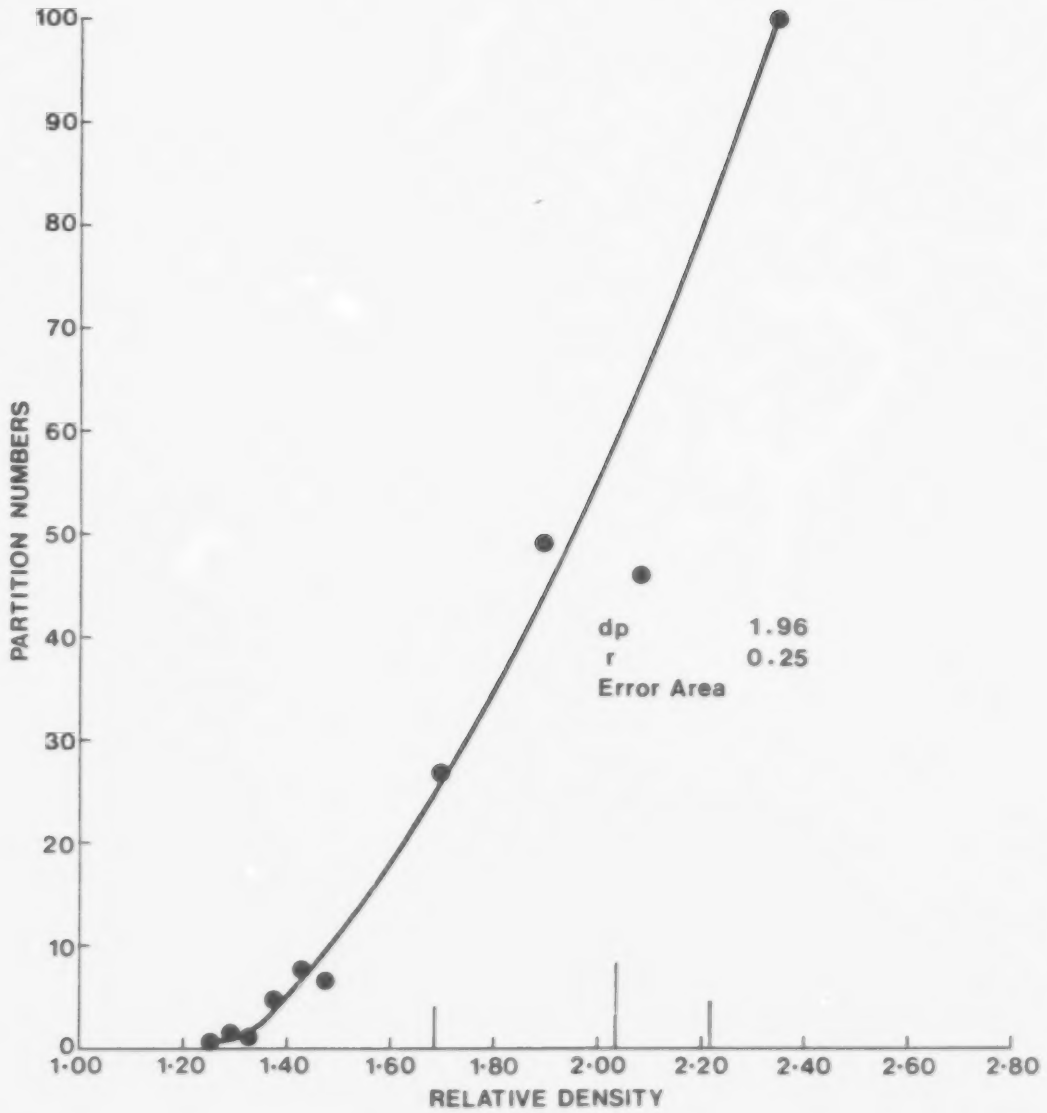
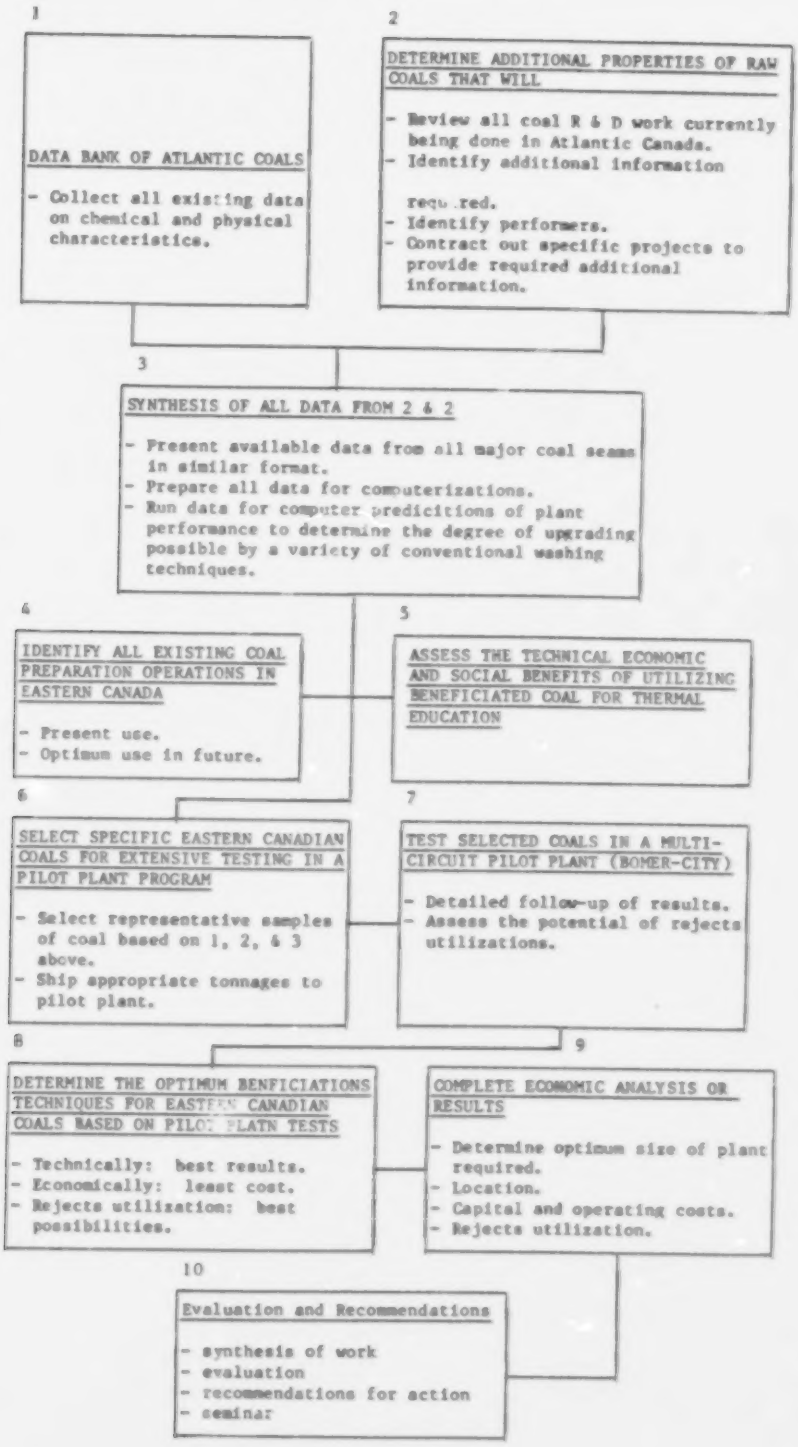


Figure 27 - Water-Only Tricone Cyclone error curve (0.6 X 0.15mm).

APPENDIX A

BENEFICIATION POTENTIAL PROGRAM ON ATLANTIC COAL


1
DATA BANK OF ATLANTIC COALS
- Collect all existing data on chemical and physical characteristics.
2
DETERMINE ADDITIONAL PROPERTIES OF RAW COALS THAT WILL
- Review all coal R & D work currently being done in Atlantic Canada.
- Identify additional information required.
- Identify performers.
- Contract out specific projects to provide required additional information.
3
SYNTHESIS OF ALL DATA FROM 2 & 2
- Present available data from all major coal seams in similar format.
- Prepare all data for computerizations.
- Run data for computer predicitions of plant performance to determine the degree of upgrading possible by a variety of conventional washing techniques.
4
IDENTIFY ALL EXISTING COAL PREPARATION OPERATIONS IN EASTERN CANADA
- Present use.
- Optimum use in future.
5
ASSESS THE TECHNICAL ECONOMIC AND SOCIAL BENEFITS OF UTILIZING BENEFICIATED COAL FOR THERMAL EDUCATION
6
SELECT SPECIFIC EASTERN CANADIAN COALS FOR EXTENSIVE TESTING IN A PILOT PLANT PROGRAM
- Select representative samples of coal based on 1, 2, & 3 above.
- Ship appropriate tonnages to pilot plant.
7
TEST SELECTED COALS IN A MULTI-CIRCUIT PILOT PLANT (BOMER-CITY)
- Detailed follow-up of results.
- Assess the potential of rejects utilizations.
8
DETERMINE THE OPTIMUM BENFICIATIONS TECHNIQUES FOR EASTERN CANADIAN COALS BASED ON PILOT PLATN TESTS
- Technically: best results.
- Economically: least cost.
- Rejects utilization: best possibilities.
9
COMPLETE ECONOMIC ANALYSIS OR RESULTS
- Determine optimum size of plant required.
- Location.
- Capital and operating costs.
- Rejects utilization.
10
Evaluation and Recommendations
- synthesis of work
- evaluation
- recommendations for action
- seminar

APPENDIX B

CMRC SUPPORT STUDIES

DONKIN-MORIEN COAL
WASH TESTS AND WASHABILITY RESULTS

DSS Contract Number
12 SC.23216-4-6121
Volume 3 of 5

forming part of the
ATLANTIC COAL BENEFICIATION POTENTIAL
SUPPORT STUDIES
for the
Department of Energy, Mines and Resources Canada
CANMET, Coal Research Laboratories, DEVON

submitted by
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December 1985

CMRC 8571-C

CMRC

ATLANTIC COAL BENEFICIATION POTENTIAL SUPPORT STUDIES

DSS Contract Number
12 SC.23216-4-6121

SCHEDULE OF REPORTS

FINAL REPORTS

Volume 1: **Prince Mine Raw Coal**
Wash Tests and Washability Results

Volume 2: **Minto Coal**
Wash Tests and Washability Results

Volume 3: **Donkin-Morien Coal**
Wash Tests and Washability Results

Volume 4: **Drying Tests and Properties of Dried Products**

Volume 5: **Summary Report** - containing:
Schedules of Samples Prepared
Schedules of Products Delivered
Progress Reports
Observations on EPRI Wash Tests at Homer City

DSS Contract Number 12SC.23216-4-6121
Volume 3 of 5
DONKIN-MORIEN COAL - WASH TESTS AND WASHABILITY RESULTS

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DONKIN-MORIEN COAL - WASH TESTS AND WASHABILITY RESULTS

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APPENDICES

Appendix 1	Data for the Size Distribution and Washability Characteristics
Appendix 2	Determination of the Relationship between Specific Energy and Ash Content
Appendix 3	Results from CANMET'S Wash Tests
Appendix 4	Data for determining Partition Curves

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DONKIN-MORIEN COAL - WASH TESTS AND WASHABILITY RESULTS

1. INTRODUCTION

1.1 Background

Eastern Canadian coals are known for their high sulphur content (2-6%). Ash removal is easily achieved by preparation resulting in low ash content, however, sulphur removal is limited. Pyritic sulphur represents 30-70% of the total sulphur and in most cases is finely disseminated and crushing and/or grinding is required to liberate it. A program for the development of beneficiation potential for eastern Canadian coals is being conducted by Energy, Mines and Resources, Canada. Part of this program is to determine the optimum beneficiation techniques for eastern Canadian coals based on pilot plant evaluation.

1.2 Selected Coals

Three coals were selected for pilot plant evaluation:

- Prince Mine Raw Coal from the Cape Breton Development Corporation's existing mine
- Minto Coal from the New Brunswick Electric Power Corporation's mine.
- Donkin-Morien Coal from the Cape Breton Development Corporation's new mine

1.3 CANMET and CMRC Services

The Donkin-Morien coal was tested at CANMET's pilot plant in Devon, Alberta.

The coal preparation laboratories and pilot plants of CANMET and the Coal Mining Research Company (CMRC) adjoin in the Coal Research Centre, Devon. As part of DSS Contract 12SC.23216-4-6121 CMRC was engaged to provide support

services to CANMET in the coal characterization and wash tests of the Donkin-Morien coal, comprising:

- Handling of the raw coal and product samples at Devon
- Characterization of the raw coal
- Analysis of the product samples
- Provision of data for determining the performance of the pilot plant.

1.4 Key Personnel

Project Manager for Energy, Mines and Resources:
Mr. Louis Sirois/Mr. E. Joe (Ottawa)
Assistant Project Manager for Energy, Mines and Resources:
Mr. Kipp Johnson (Sydney)
Contact Person for Cape Breton Development Corporation:
Mr. John C. Campbell
CANMET Scientific Officer:
Mr. Magdy W. Mikhail
CMRC Principal Investigator:
Mr. Stanley G. Butcher
CMRC Operations Engineer:
Mr. Peter S. McIntosh

On a day to day basis the CMRC services were provided as requested by the Scientific Officer (or his plant technician Mr. Orst Humeniuk): generally by verbal instructions to Mr. Peter McIntosh and his staff.

1.5 Reporting and Interpretation of Data

Interpretation of the data was the responsibility of CANMET. Analyses were passed as soon as available to the Scientific Officer.

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DONKIN-MORIEN COAL - WASH TESTS AND WASHABILITY RESULTS

The program conducted by CMRC was designed by the Scientific Officer to provide, firstly, the information required for Energy, Mines and Resources current studies. The needs of the Cape Breton Development Corporation for possible full scale plant design information were also taken into account.

This volume summarizes and places on permanent record the data obtained by CMRC for the Donkin-Morien coal.

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DONKIN-MORIEN COAL - WASH TESTS AND WASHABILITY RESULTS

2. CHARACTERISTICS OF DONKIN-MORIEN COAL

Donkin-Morien is a new mine under development. A run-of-mine coal sample was produced as soon as the development workings had advanced to permit its proper extraction. The coal seam has a high sulphur content. The relatively thick seam is banded and some bands contain lower sulphur contents than others. The sample was mined to simulate the anticipated production method which will leave high sulphur roof and floor coal in place. Thus the sample contained very little free refuse and was of low ash content. This coal would not require washing on account of ash content.

2.1 Head Sample Analysis

Table 1 shows the analysis of the head sample of Donkin-Morien raw coal.

2.2 Size Distribution

2.2.1 Introduction - Conventional Raw Coal Feed

The Donkin-Morien coal as received was a nominal 50 mm x 0 product which had been screened, the coarser coal crushed, and blended at the mine site. This would be the normal feed to a conventional washing scheme for this coal. This bulk sample was loaded into nominal 1 tonne capacity lined bags for shipment to CRC, Devon.

Conventional size distribution tests were therefore conducted on the as received 50 mm x 0 raw coal. This sample was dry screened down to 0.6 mm and wet screened below 0.6 mm.

Table 1 Head Sample Analysis of Donkin-Morien Coal

Proximate Analysis

	As Recieved	Air Dried	Dry Basis
Moisture	3.90%	1.17%	.00%
Volatile Matter	34.21%	35.18%	35.60%
Ash	7.92%	8.14%	8.24%
Fixed Carbon	53.97%	55.51%	56.16%

Ultimate Analysis

	Air Dried
Moisture	1.17%
Fixed Carbon	74.75%
Hydrogen	4.88%
Nitrogen	1.39%
Ash	8.14%
Sulphur	3.36%
Oxygen	6.31%

Forms of Sulphur

	Air Dried
Pyritic	1.86%
Sulphate	.19%
Total	3.36%

Analysis of Ash

SiO2	35.75%
Al2O3	21.07%
TiO2	.43%
Fe2O3	31.35%
CaO	5.14%
MgO	.52%
Na2O	.71%
K2O	.64%
P2O5	.25%
SO3	2.02%
Undetermined	2.12%

2.2.2 Size Degradation During Washing

Many coals degrade significantly when they are mixed with water and pumped through preparation plant circuits. In some cases this degradation can be so severe that, if the plant is designed using a size distribution determined from conventional screening only, the capacity of the fines cleaning section will be seriously undersized.

The degree of degradation is not necessarily a function of the hardness of the coal. Often, a hard coal will degrade because it contains clay that swells and breaks down in water.

Over the past five years both CANMET and CMRC have adopted the Standards Association of Australia's drum tumbler test (wet attrition test) as a means of predicting this degradation during washing. Basically, this test involves putting 50 kg of coal along with 150 L of water and 20 steel cubes into a 200 L steel drum which is then tumbled end-over-end for a set amount of time determined from a formula based on the coal's Hardgrove Grindability Index (HGI). After tumbling, the drum's contents are poured over a 0.6 mm screen. The fraction retained on the screen is air dried and dry screened. A representative sample of the slurry passing through the screen is wet screened.

Table 2 gives the size distribution, ash and specific energy data determined for the as received (50 mm x 0) Donkin-Morien coal by both the conventional and wet attrition procedures.

2.2.3 CANMET's Devon Pilot Plant Feed

This plant is designed to receive a nominal 10 mm x 0 raw coal feed. After crushing head samples to -10 mm the size distribution was determined:

- conventional size distribution by dry and wet screening as described in 2.2.1 above
- following the wet drum tumbler test as described in 2.2.2 above.

Table 3 gives the size distribution, ash and specific energy data obtained from both methods for the Donkin-Morien coal crushed to 10 mm nominal top size.

Appendix 1, Tables 1-4 give the raw data for these values. (The crushing, wet drum tumbling, screening and sample preparation was done by CMRC staff. The analyses were conducted under sub-contract by Birtley Coal Testing Ltd. of Calgary).

2.3 Washability

2.3.1 Pre-Testing Observations

Current practice recognizes that the washability can be significantly altered to give, in many cases, more liberation of ash and sulphur bearing minerals according to the way in which the coal is broken by crushing and/or wet degradation. Donkin-Morien coal is hard (Hardgrove grindability index = 57) and, as already explained, did not contain much refuse. It did not break down significantly during the wet attrition tests.

In the first stage of the CANMET pilot plant the feed coal falls into a tank of water and is then pumped to a screen. This mixing with water and pumping probably degrades the coal to a similar degree as the wet attrition tests. For this reason, we used the degraded coal from the wet attrition test to determine the washability characteristics of the pilot plant feed (10 mm x 0).

For the same reason the washability analyses of the as received raw coal were conducted on the size fractions from the wet attrition tests of the 50 mm x 0

VOLUME 3 - TABLE 2

SIZE ANALYSIS OF THE AS RECIEVED (-50 mm) DONKIN-MORIEN COAL

Size (mm)	% Mass		% Ash		% Sulphur		Specific Energy *	
	Unattrited	Attrited	Unattrited	Attrited	Unattrited	Attrited	Unattrited (MJ/kg)	Attrited (MJ/kg)
+25	2.61	3.32	12.28	3.25	5.58	1.72	30.57	34.23
25x9.5	20.98	18.56	4.88	7.71	3.05	3.79	33.49	32.57
9.5x6.7	12.62	12.83	4.93	6.10	2.68	3.09	33.39	32.91
6.7x1.7	36.09	37.25	4.89	5.09	3.08	2.98	33.25	33.27
1.7x0.6	12.38	11.24	5.65	4.98	2.99	2.71	32.86	33.23
0.6x0.3	4.10	5.13	5.59	4.05	2.79	2.32	32.23	33.36
0.3x0.15	3.12	3.27	6.60	6.08	2.79	2.47	31.71	32.56
0.15x0.075	2.29	2.26	8.22	7.73	2.92	2.77	30.74	31.69
0.075x0.045	1.22	1.33	8.81	8.20	3.16	2.88	30.79	31.48
-0.045	4.59	4.81	12.65	13.84	3.15	2.86	29.94	29.59
Total	100.00	100.00	5.74	6.13	3.06	3.01	32.87	32.87

All figures are on a dry basis.

* Specific Energy values determined experimentally.

VOLUME 3 - TABLE 3

SIZE ANALYSIS OF THE CRUSHED (-10 mm) DONKIN-MORIEN COAL

Size (mm)	% Mass		% Ash		% Sulphur		Specific Energy *	
	Unattrited	Attrited	Unattrited	Attrited	Unattrited	Attrited	Unattrited (MJ/kg)	Attrited (MJ/kg)
+12.5	2.19	2.21	8.85	8.64	3.27	4.13	31.91	31.95
12.5x6.7	26.12	23.80	8.34	5.12	4.67	3.11	31.86	33.28
6.7x1.7	42.00	40.13	5.30	4.96	3.00	2.95	33.19	33.31
1.7x0.6	14.33	14.17	5.52	5.31	2.78	2.92	32.87	33.01
0.6x0.3	4.62	6.21	5.65	5.57	2.65	2.79	32.51	32.70
0.3x0.15	3.18	3.99	6.80	6.89	2.76	2.83	31.82	32.13
0.15x0.075	2.23	2.77	8.22	8.12	2.95	3.02	31.28	31.54
0.075x0.045	1.13	1.75	9.33	8.64	3.10	2.99	31.37	31.48
-0.045	4.20	4.97	12.75	13.61	2.93	3.07	29.77	29.75
Total	100.00	100.00	6.69	5.29	3.38	3.00	32.49	32.89

All figures are on a dry basis.

* Specific Energy values determined experimentally.

material. (The proximate analyses of these fractions are being undertaken by CANMET).

The specific gravity intervals for the float-sink analyses were agreed with the Scientific Officer to provide the data required for interpretation of the pilot plant test washes and possible full scale plant design.

2.3.2 Washability Characteristics

Table 4 shows the washability of the crushed (-10 mm) coal from the wet attrition test. (Appendix 1, Tables 5 and 6 contain the raw data for this table. A cumulative float-sink procedure was used for the 0.6 x 0.15 mm size fraction. There are sometimes problems with this method - in this case the 1.30 floats gave a higher ash content than the 1.35 floats. Appendix 1, Table 7, shows the adjusted data.)

As expected there was very little free shale (2.17 sinks material). From the percentages of intermediate specific gravity material it can be seen that this coal would not be difficult to clean for ash content if this should become necessary, for example as a result of changed mining conditions.

The sulphur content is seen to increase with increasing specific gravity. Thus the rejects from cleaning processes would have a high sulphur content. However, since there is a relatively small proportion of higher specific gravity material there would not be a large overall percentage sulphur reduction achieved.

2.4 Relationship between Specific Energy and Ash Content

A lot of the wash test data data has to be interpreted into mass and energy balances. The required degree of accuracy can best be obtained, without having to perform an excessive number of calorimetric determinations, by establishing the linear relationship between specific energy and ash content for the particular coal.

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By agreement with the Scientific Officer the specific energy values were determined on the size fraction increments reported in Appendix 1, Tables 4 - 6. These were converted to dry basis and the data processed as reported in Appendix 2.

From a linear regression of specific energy on ash we obtained:

$$SE = 35.33 - 0.43\ A$$

where SE is the specific energy in MJ/kg (dry basis) and A is the % ash (dry basis).

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3. PILOT PLANT WASH TESTS

3.1 Objectives and Set-up Tests

Objectives for the pilot plant wash tests had been agreed in principle at a meeting in Ottawa in November 1984. Nine wash tests (including set-up tests) were conducted, each of which is summarized in Appendix 3.

CMRC prepared and analyzed the samples collected by CANMET staff during these test washes and passed results as soon as available to the Scientific Officer.

3.2 Selected Test Results for Evaluation Report

CANMET selected for detailed analysis and inclusion in their Evaluation Report three donkin-Morien coal wash tests which met the objectives. These are summarized in Table 5.

CMRC sent the selected feed and product samples from the selected wash tests, numbers 2, 7 and 9 to Birtley Coal Testing Ltd. of Calgary. They conducted, under sub-contract, the float-sink and proximate analysis. Appendix 4 contains these results, from which partition curves may be calculated.

3.3 Observations

One problem that plagued the wash tests using the dense medium cyclone circuit was poor performance of the drain and rinse screens for wsahing the magnetite from the cyclone products. As a result, the products from these wash tests may contain significant amounts of magnetite. This would cause the determined ash contents to be abnormally high.

VOLUME 3 - TABLE 4

WASHABILITY OF THE CRUSHED (-10 mm) DONKIN-MORIEN COAL FROM THE WET ATTRITION TEST

a) Washability of the +0.6 mm Coal

Specific Gravity Fraction	% Mass	% Ash	% Sulphur	Specific Energy* (MJ/kg)
-1.275	41.46	0.69	1.22	35.17
1.275x1.30	32.00	2.47	2.13	34.31
1.30x1.35	12.19	5.08	3.43	33.25
1.35x1.40	4.40	9.27	4.96	31.61
1.40x1.45	2.69	12.87	7.43	30.00
1.45x1.50	1.05	17.71	9.03	28.06
1.50x1.60	1.07	22.35	10.38	26.34
1.60x1.80	1.30	30.88	12.64	22.95
1.80x2.00	0.65	39.40	16.82	19.19
2.00x2.17	0.38	46.55	18.77	15.98
+2.17	2.81	74.17	17.14	4.90
Total	100.00	5.79	3.06	33.01

*Specific Energy values determined experimentally.

b) Washability of the 0.6x0.15 mm Coal

Specific Gravity Fraction	% Mass	% Ash	% Sulphur	Specific Energy** (MJ/kg)
-1.275	24.96	0.48	1.29	34.93
1.275x1.30	32.45	0.80	1.38	34.64
1.30x1.35	27.78	2.62	2.44	33.79
1.35x1.40	4.68	5.35	3.81	32.62
1.40x1.50	3.64	14.15	7.68	29.95
1.50x1.80	2.22	30.35	11.28	23.36
1.80x2.17	1.23	43.61	13.15	16.80
+2.17	3.04	69.33	13.94	3.94
Total	100.00	5.19	2.44	32.81

**Calculated from SE = 35.33-0.43 Ash

All figures are on a dry basis.

TABLE 5 : SUMMARY OF THE WASH TEST RESULTS

Wash Test		2	7	9
Method of Cleaning				
+0.5 mm		Batac Jig	Dense Medium Cyclone	Dense Medium Cyclone
0.5 x 0.15 mm		Compound Water Cyclone	Compound Water Cyclone	Compound Water Cyclone
0.15 x 0 mm		Froth Flotation	Froth Flotation	Froth Flotation
Results				
Feed	% Ash	6.76	5.35	5.35
	% Sulphur	3.45	3.21	3.19
Product	% Ash	3.27	2.04	1.85
	% Sulphur	2.49	1.96	1.74
Rejects	% Ash	49.15	19.90	14.61
	% Sulphur	15.96	7.61	5.62
% Yield (from weights)		91.57	65.43	50.09
% Energy Recovery *		95.74	68.25	52.38
% Sulphur Removed **		33.91	60.05	72.68

All figures are on a dry basis.

* The energy recovery is determined using the equation in section 2.4.

** The sulphur removal is determined using the feed and product sulphur contents.

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DONKIN-MORIEN COAL - WASH TESTS AND WASHABILITY RESULTS

4. ASSOCIATED WORK

CMRC is testing the products from the Donkin-Morien coal wash tests to determine their drying and handleability characteristics. The results from these tests will be presented in a separate report: Volume 4.

CMRC has dispatched product samples from these tests to CANMET's Combustion Research Laboratories in Ottawa. CRMC has also retained prepared samples of all fractions for any required check analyses. A log of all these samples is given in an appendix to Volume 5.

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DONKIN-MORIEN COAL - WASH TESTS AND WASHABILITY RESULTS

APPENDIX 1

Table 1	Wet Attrition Size Analysis of As Received Donkin-Morien Coal
Table 2	Conventional Size Analysis of As Received Donkin-Morien Coal
Table 3	Wet Attrition Size Analysis of Crushed (-10 mm) Donkin-Morien Coal
Table 4	Conventional Size Analysis of Crushed (-10 mm) Donkin-Morien Coal
Table 5	Float-Sink Analysis of a Subsample of the +0.6 mm Coal from the Wet Attrition Test of Crushed (-10 mm) Donkin-Morien Coal
Table 6	Float-Sink Analysis of a Subsample of the 0.6 x 0.15 mm fraction from the Wet Attrition Test of Crushed (-10 mm) Donkin-Morien Coal
Table 7	Float-Sink Analysis of a Subsample of the +0.6 mm fraction from the Unattrited As Received Donkin-Morien Coal
Table 8	Float-Sink Analysis of a Subsample of the 0.6 x 0.15 mm fraction from the Unattrited As Received Donkin-Morien Coal

VOLUME 3 - APPENDIX 1

TABLE 1

WET ATTRITION SIZE ANALYSIS OF AS RECIEVED DONKIN-MORIEN COAL

Total Sample Mass= 49.725 kg at 2.00% moisture
Mass of the Coarse Fraction After Attrition=46.445 kg

a) Dry Size Analysis of the Entire Coarse Fraction

Size (mm)	Mass (kg)	Mass (%)	% Moisture	% Ash	%Sulphur	C.V. (Cal/g)
+50	0.180	0.39	1.50	3.20	1.70	8053
50x25	1.465	3.15				
25x8.0	9.175	19.75	1.40	7.60	3.74	7670
8.0x6.7	6.355	13.68	1.60	6.00	3.05	7735
6.7x1.7	18.470	39.77	1.70	5.00	2.93	7811
1.7x0.6	5.570	11.99	1.70	4.90	2.68	7804
0.6x0	5.230	11.26	-	-	-	
Total	46.445	100.00				

b) Wet Size Analysis of a Subsample of the Fine Fraction and the -0.6 mm Coal from the Coarse Fraction

Size (mm)	Mass (g)	Mass (%)	% Moisture	% Ash	%Sulphur	C.V. (Cal/g)
0.6x0.3	357.2	30.52	1.20	4.00	2.29	7873
0.3x0.15	228.3	19.51	1.30	6.00	2.44	7675
0.15x0.075	157.3	13.44	1.00	7.65	2.75	7495
0.075x0.045	92.8	7.93	1.20	8.10	2.85	7429
0.045x0	334.6	28.59	1.00	13.70	2.84	6997
Total	1170.2	100.00				

All figures are as recieved

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TABLE 2

CONVENTIONAL SIZE ANALYSIS OF THE AS RECIEVED DONKIN-MORIEN COAL

a) Dry Size Analysis of the Entire Sample

Size (mm)	Mass (kg)	Mass (%)	% Moisture	% Ash	%Sulphur	C.V. (Cal/g)
+50	0.0	0.00	-	-	-	-
50x25	0.680	2.60	1.50	12.10	5.50	7192
25x8.0	5.480	20.94	1.70	4.80	3.00	7862
8.0x6.7	3.295	12.59	1.65	4.85	2.64	7843
6.7x1.7	9.445	36.08	1.90	4.80	3.02	7792
1.7x0.6	3.240	12.38	1.80	5.55	2.94	7707
0.6x0	4.035	15.42	-	-	-	
Total	26.175	100.00				

b) Wet Size Analysis of a Subsample of the -0.6 mm Fraction

Size (mm)	Mass (g)	Mass (%)	% Moisture	% Ash	%Sulphur	C.V. (Cal/g)
0.6x0.3	54.5	26.85	1.60	5.50	2.75	7574
0.3x0.15	41.4	20.39	1.50	6.50	2.75	7459
0.15x0.075	30.3	14.93	1.45	8.10	2.88	7237
0.075x0.045	16.1	7.93	1.30	8.70	3.12	7258
0.045x0	60.7	29.90	1.20	12.50	3.12	7065
Total	203.0	100.00				

All figures are as recieved

VOLUME 3 - APPENDIX 1

TABLE 3

WET ATTRITION SIZE ANALYSIS OF CRUSHED (-10 mm) DONKIN-MORIEN COAL

Total Sample Mass = 54.005 kg at 7.86 % moisture
Mass of the Coarse Fraction After Attrition = 46.104 kg

a) Dry Size Analysis of the Entire Coarse Fraction

Size (mm)	Mass (kg)	Mass (%)	% Moisture	% Ash	%Sulphur	Specific Energy (MJ/kg)
+12.5	1.105	2.44	0.96	8.56	4.10	31.644
12.5x6.7	11.965	26.46	1.03	5.07	3.08	32.936
6.7x1.7	20.220	44.71	1.25	4.90	2.92	32.892
1.7x0.6	7.130	15.77	1.08	5.25	2.89	32.658
0.6x0	4.800	10.61	-	-	-	
Total	45.220	100.00				

b) Wet Size Analysis of a Subsample of the Fine Fraction and the -0.6mm Coal in the Coarse Fraction

Size (mm)	Mass (g)	Mass (%)	% Moisture	% Ash	%Sulphur	Specific Energy (MJ/kg)
0.6x0.3	474.0	31.56	0.46	5.55	2.78	32.548
0.3x0.15	304.4	20.27	0.47	6.86	2.82	31.982
0.15x0.075	211.4	14.08	0.36	8.09	3.01	31.430
0.075x0.045	133.5	8.89	0.39	8.61	2.98	31.355
0.045x0	378.5	25.20	0.02	13.61	3.07	29.739
Total	1501.8	100.00				

All figures are as recieved

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TABLE 4

CONVENTIONAL SIZE ANALYSIS OF THE CRUSHED (-10 mm) DONKIN-MORIEN COAL

a) Dry Size Analysis of the Entire Sample

Size (mm)	Mass (kg)	Mass (%)	% Moisture	% Ash	%Sulphur	C.V. (Cal/g)
+12.5	0.650	2.18	1.75	8.70	3.22	7494
12.5x6.7	7.765	26.06	1.65	8.20	4.60	7488
6.7x1.7	12.515	42.00	1.90	5.20	2.95	7781
1.7x0.6	4.280	14.36	2.15	5.40	2.72	7693
0.6x0	4.590	15.40	-	-	-	
Total	29.800	100.00				

b) Wet Size Analysis of a Subsample of the -0.6mm Fraction

Size (mm)	Mass (g)	Mass (%)	% Moisture	% Ash	%Sulphur	C.V. (Cal/g)
0.6x0.3	225.2	29.93	0.90	5.60	2.63	7700
0.3x0.15	156.1	20.75	1.40	6.70	2.73	7498
0.15x0.075	109.4	14.54	1.40	8.10	2.91	7370
0.075x0.045	55.5	7.38	1.40	9.20	3.06	7392
0.045x0	206.1	27.40	1.20	12.60	2.90	7030
Total	752.3	100.00				

All figures are as recieved

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TABLE 5

FLOAT/SINK ANALYSIS OF A SUBSAMPLE OF THE +0.6 mm FRACTION FROM THE WET ATTRITION TEST OF CRUSHED (-10 mm) DONKIN-MORIEN COAL

Specific Gravity Fraction	Mass (g)	Mass (%)	% Moisture	% Ash	% Sulphur	Specific Energy (MJ/kg)
1.25 Float	112.6	2.26	0.85	0.71	1.05	35.26
1.25-1.275	1957.2	39.24	1.17	0.68	1.15	34.74
1.275-1.30	1597.8	32.03	1.16	2.44	2.11	33.91
1.30-1.35	607.3	12.17	0.98	5.04	3.40	32.93
1.35-1.40	219.0	4.39	0.89	9.19	4.92	31.34
1.40-1.45	133.6	2.68	0.74	12.78	7.38	29.78
1.45-1.50	52.2	1.05	0.75	17.58	8.97	27.85
1.50-1.60	53.4	1.07	0.74	22.19	10.30	26.15
1.60-1.80	64.5	1.29	0.75	30.65	12.55	22.78
1.80-2.00	32.5	0.65	0.72	39.12	16.70	19.05
2.00-2.17	18.7	0.38	0.62	46.26	18.65	15.89
2.17 Sink	139.4	2.79	0.54	73.77	17.05	4.88
Total	4988.2	100.00				

All figures are as recieved

VOLUME 3 - APPENDIX 1

TABLE 6

FLOAT/SINK ANALYSIS OF A SUBSAMPLE OF THE 0.6x0.15 mm FRACTION FROM THE WET ATTRITION TEST OF CRUSHED (-10 mm) DONKIN-MORIEN COAL

Specific Gravity Fraction		Mass (%)	% Ash	% Sulphur	Specific Energy (MJ/kg)
1.275	Floats	24.96	0.48	1.29	34.93
	Sinks	75.04	6.76	3.20	32.10
1.30	Floats	57.41	0.66	1.34	34.76
	Sinks	42.59	11.30	4.59	30.17
1.35	Floats	85.19	1.30	1.70	34.49
	Sinks	14.81	27.57	8.64	23.37
1.40	Floats	89.87	1.51	1.81	34.35
	Sinks	10.13	37.84	10.80	19.10
1.50	Floats	93.51	2.00	2.04	34.18
	Sinks	6.49	51.12	12.65	13.07
1.80	Floats	95.73	2.66	2.25	34.01
	Sinks	4.27	61.92	13.36	7.64
2.17	Floats	96.96	3.18	2.39	33.76
	Sinks	3.04	69.33	13.45	3.94

All figures are dry basis

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TABLE 7

FLOAT/SINK ANALYSIS OF A SUBSAMPLE OF THE
+0.6 mm FRACTION FROM THE UNATTRITED
AS RECIEVED DONKIN-MORIEN COAL

Specific Gravity Fraction	Mass (kg)	Mass (%)	% Ash	% Sulphur
1.275 Float	17.76	35.11	0.98	1.29
1.275-1.30	16.91	33.44	1.92	1.90
1.30-1.35	7.61	15.02	5.50	3.47
1.35-1.40	2.17	4.28	9.19	5.04
1.40-1.45	1.10	2.16	12.31	6.21
1.45-1.50	0.61	1.19	16.28	7.48
1.50-1.60	0.57	1.11	21.24	8.73
1.60-1.80	0.64	1.26	29.91	10.93
1.80-2.00	0.43	0.83	37.77	13.56
2.00-2.17	0.27	0.51	47.75	15.22
2.17 Sink	2.54	5.09	65.84	27.34
Total	50.59	100.00		

All Masses (kg) are as recieved.
All other figures are dry basis.

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TABLE 7

FLOAT/SINK ANALYSIS OF A SUBSAMPLE OF THE +0.6 mm FRACTION FROM THE UNATTRITED AS RECIEVED DONKIN-MORIEN COAL

Specific Gravity Fraction	Mass (kg)	Mass (%)	% Ash	% Sulphur
1.275 Float	17.76	35.11	0.98	1.29
1.275-1.30	16.91	33.44	1.92	1.90
1.30-1.35	7.61	15.02	5.50	3.47
1.35-1.40	2.17	4.28	9.19	5.04
1.40-1.45	1.10	2.16	12.31	6.21
1.45-1.50	0.61	1.19	16.28	7.48
1.50-1.60	0.57	1.11	21.24	8.73
1.60-1.80	0.64	1.26	29.91	10.93
1.80-2.00	0.43	0.83	37.77	13.56
2.00-2.17	0.27	0.51	47.75	15.22
2.17 Sink	2.54	5.09	65.84	27.34
Total	50.59	100.00		

All Masses (kg) are as recieved.
All other figures are dry basis.

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DONKIN-MORIEN COAL - WASH TESTS AND WASHABILITY RESULTS

APPENDIX 2

Multiple Linear Regression Analysis
Specific Energy Versus % Ash for
Donkin-Morien Coal

$Y = 35.33 - 0.43\,x$

Y: Specific Energy in MJ/kg (dry basis)

X: % Ash (dry basis)

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APPENDIX 3

SCHEDULE OF WASH TESTS

Date	Wash Test Number	Type of Test	Methods of Cleaning* (+0.5 mm)	(-0.15mm)	Results to ** Evaluation Report
May 15, 1985	1	Set up	Jig	Froth Flotation	-
May 29, 1985	2	Full	Jig	Froth Flotation	Yes
June 6, 1985	3	Set up	HMC	Froth Flotation	-
June 13, 1985	4	Set up	HMC	Froth Flotation	-
June 24, 1985	5	Set up	HMC	Froth Flotation	-
July 10, 1985	6	Set up	HMC	Not Cleaned	-
July 19, 1985	7	Full	HMC	Froth Flotation	Yes
Oct. 15, 1985	8	Set up	HMC	Froth Flotation	-
Oct. 18, 1985	9	Full	HMC	Froth Flotation	Yes

HMC - Heavy Medium Cyclone
The 0.5 x 0.15 mm coal was washed in a Compound Water Only Cyclone circuit in all the tests.

** Only the results from full test were considered for detailed evaluation. If successful they were accepted for the Evaluation Report. Selected products were analysed to provide data for partition curves.

COAL MINING RESEARCH COMPANY

TABLE 1
MATERIAL TESTED: DONKIN-MORIEN
WASH TEST: 1
DATE: May 15,1985

1) Feed and Products

	% Moisture	% Ash+	% Sulphur+	Specific Energy* (MJ/kg)	Total Mass+ (t)
Feed	3.68	8.09	3.57	31.85	2.16
Clean Coal	9.29	3.62	2.49	33.77	2.06
Coarse Rejects	14.50	43.92	14.26	16.44	0.08
Fine Rejects	6.42	43.37	13.96	16.68	0.02

2) Coarse Cleaning (Batac Jig)

	% Solids	% Ash+	% Sulphur+
Deslime Screen Overflow	65.51	6.81	3.47
Clean Coal	61.97	3.52	2.45
Rejects	77.64	48.95	14.06

3) Compound Water Only Cyclone Circuit

	% Solids	% Ash+	% Sulphur+
Deslime Screen Underflow	3.42	7.55	3.13
CWC OU (Clean Coal)	39.64	4.28	2.53
CWC UU (Rejects)	8.23	48.36	15.23

4) Froth Flotation

	% Solids	% Ash+	% Sulphur+
Feed	1.66	10.04	3.28
Product from Cell 1	21.55	3.31	2.17
Product from Cell 2	17.28	4.83	2.32
Tailings	0.54	20.43	4.64

+ dry basis
* Calculated from: S.E.(db) = 35.33 - 0.43 * %Ash(db).

COAL MINING RESEARCH COMPANY

TABLE 2
MATERIAL TESTED: DONKIN-MORIEN
WASH TEST: 2
DATE: May 29,1985

1) Feed and Products

	% Moisture	% Ash+	% Sulphur+	Specific Energy* (MJ/kg)	Total Mass+ (t)
Feed	3.23	6.76	3.45	32.42	5.93
Clean Coal	7.70	3.27	2.49	33.92	5.43
Coarse Rejects	12.80	52.38	17.28	12.81	0.37
Fine Rejects	12.29	39.96	12.19	18.15	0.13

2) Coarse Cleaning (Batac Jig)

	% Solids	% Ash+	% Sulphur+
Deslime Screen Overflow	69.51	6.02	3.29
Clean Coal	64.18	2.97	2.46
Rejects	73.50	48.93	15.57

3) Compound Water Only Cyclone Circuit

	% Solids	% Ash+	% Sulphur+
Deslime Screen Underflow	3.58	6.90	3.40
CWC OU (Clean Coal)	32.03	4.12	2.58
CWC UU (Rejects)	12.79	51.75	15.77
Linatex Overflow	1.12	7.77	2.64
Linatex Underflow	13.58	5.50	2.98
Derrick Screen Underflow	4.10	17.92	6.14

4) Froth Flotation

	% Solids	% Ash+	% Sulphur+
Feed	1.51	10.30	3.58
Product from Cell 1	20.18	3.79	2.30
Product from Cell 2	7.58	6.30	2.95
Tailings	NA	39.69	6.73

5) Dewatering Circuit

	% Solids	% Ash+	% Sulphur+
Thickener Feed	0.07	35.42	5.76
Thickener Overflow	0.01	41.25	5.56
Thickener Underflow	0.81	53.61	13.68
Clean Coal Centrifuge Effluent	5.16	4.63	2.64
Reject Centrifuge Effluent	0.25	36.02	3.73

6) Timed Samples

	% Solids	% Ash+	% Sulphur+	Mass+ Flowrate (kg·min)
Linatex Overflow	0.90	7.32	2.55	4.07
CWC OU	26.95	4.83	2.74	4.14
CWC UU	11.02	55.44	16.57	0.32

+ dry basis
* Calculated from: S.E.(db) = 35.33 - 0.43 * %Ash(db).

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TABLE 3
MATERIAL TESTED: DONKIN-MORIEN
WASH TEST: 3
DATE: June 6,1985

1) Feed and Products

	% Moisture	% Ash+	% Sulphur+	Specific Energy* (MJ/kg)	Total Mass+ (t)
Feed	3.40	7.37	3.62	32.16	1.59
Clean Coal	8.60	3.06	2.14	34.01	1.40
Coarse Rejects	27.09	41.93	14.58	17.30	0.13
Fine Rejects	10.69	35.25	10.37	20.17	0.07

2) Coarse Cleaning (Dense Medium Cyclone)

	% Solids	% Ash+	% Sulphur+
Deslime Screen Overflow	68.22	5.76	3.13
Clean Coal	73.57	3.45	2.18
Rejects	82.70	45.69	15.49

3) Compound Water Only Cyclone Circuit

	% Solids	% Ash+	% Sulphur+
Deslime Screen Underflow	2.66	8.61	2.73
CWC OU (Clean Coal)	27.32	3.58	2.20
CWC UU (Rejects)	8.43	47.15	15.41

4) Froth Flotation

	% Solids	% Ash+	% Sulphur+
Feed	1.49	12.90	2.96
Product from Cell 1	19.29	3.43	2.00
Product from Cell 2	7.33	4.96	2.31
Tailings	0.13	35.45	4.26

+ dry basis
* Calculated from: S.E.(db) = 35.33 - 0.43 * %Ash(db).

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TABLE 4
MATERIAL TESTED: DONKIN-MORIEN
WASH TEST: 4
DATE: June 13,1985

1) Feed and Products

	% Moisture	% Ash+	% Sulphur+	Specific Energy* (MJ/kg)	Total Mass+ (t)
Feed	2.60	6.87	3.65	32.38	1.83
Clean Coal	9.52	3.30	2.30	33.91	1.60
Coarse Rejects	23.29	42.49	14.17	17.06	0.14
Fine Rejects	13.82	34.60	7.05	20.45	0.10

2) Coarse Cleaning (Dense Medium Cyclone)

	% Solids	% Ash+	% Sulphur+
Deslime Screen Overflow	67.12	5.70	3.35
Clean Coal	74.63	2.84	2.20
Clean Coal (Rinsed)	NA	2.30	2.18
Rejects	81.89	44.75	14.78

3) Compound Water Only Cyclone Circuit

	% Solids	% Ash+	% Sulphur+
Deslime Screen Underflow	2.80	8.53	2.71
CWC OU (Clean Coal)	28.84	3.87	2.39
CWC UU (Rejects)	7.96	47.85	15.37
Linatex Overflow	1.38	9.53	2.26

4) Froth Flotation

	% Solids	% Ash+	% Sulphur+
Feed	1.76	14.58	3.22
Product from Cell 1	19.08	3.67	2.21
Product from Cell 2	7.45	5.52	2.54
Tailings	0.15	61.10	4.31

+ dry basis
* Calculated from: S.E.(db) = 35.33 - 0.43 * %Ash(db).

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TABLE 5
MATERIAL TESTED: DONKIN-MORIEN
WASH TEST: 5
DATE: June 24,1985

1) Feed and Products

	% Moisture	% Ash+	% Sulphur+	Specific Energy* (MJ/kg)	Total Mass+ (t)
Feed	3.32	6.92	3.61	32.36	2.41
Clean Coal	8.76	2.32	2.06	34.33	1.79
Coarse Rejects	28.80	26.22	9.23	24.06	0.38
Fine Rejects	14.79	20.97	5.37	26.32	0.25

2) Coarse Cleaning (Dense Medium Cyclone)

	% Solids	% Ash+	% Sulphur+
Deslime Screen Overflow	68.06	5.44	3.21
Clean Coal	68.57	2.39	2.14
Clean Coal (Rinsed)	NA	2.23	2.12
Rejects	69.69	25.15	9.71

3) Compound Water Only Cyclone Circuit

	% Solids	% Ash+	% Sulphur+
Deslime Screen Underflow	2.63	7.32	2.92
CWC OU (Clean Coal)	13.77	3.08	2.17
CWC UU (Rejects)	5.91	45.29	14.45

4) Froth Flotation

	% Solids	% Ash+	% Sulphur+
Feed	1.32	8.57	2.83
Product from Cell 1	22.61	3.40	2.11
Product from Cell 2	9.22	4.64	2.37
Tailings	0.30	24.78	4.24

+ dry basis
* Calculated from: S.E.(db) = 35.33 - 0.43 * %Ash(db).

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TABLE 6
MATERIAL TESTED: DONKIN-MORIEN
WASH TEST: 6
DATE: July 10,1985

1) Feed and Products

	% Moisture	% Ash+	% Sulphur+	Specific Energy* (MJ/kg)	Total Mass+ (t)
Feed	NA	NA	NA	NA	NA
Clean Coal	8.33	2.06	2.01	34.45	NA

2) Coarse Cleaning (Dense Medium Cyclone)

	% Solids	% Ash+	% Sulphur+
Clean Coal	69.32	2.03	2.05
Rejects	69.07	23.44	10.77

+dry basis
* Calculated from: S.E.(db) = 35.33 - 0.43 * %Ash(db).

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TABLE 7
MATERIAL TESTED: DONKIN-MORIEN
TEST WASH: 7
DATE: July 19,1985

1) Feed and Products

	% Moisture	% Ash+	% Sulphur+	Specific Energy* (MJ/kg)	Total Mass+ (t)
Feed	2.67	5.35	3.21	33.03	4.05
Clean Coal	9.68	2.04	1.96	34.45	2.65
Coarse Rejects	32.84	20.14	8.58	26.67	1.04
Fine Rejects	16.66	19.19	4.82	27.08	0.36

2) Coarse Cleaning (Dense Medium Cyclone)

	% Solids	% Ash+	% Sulphur+
Deslime Screen Overflow	68.77	5.42	3.34
Clean Coal	70.05	1.89	1.89
Clean Coal (Rinsed)	NA	1.79	1.91
Rejects	73.59	19.96	8.27

3) Compound Water Only Cyclone Circuit

	% Solids	% Ash+	% Sulphur+
Deslime Screen Underflow	3.67	5.29	2.43
CWC OU (Clean Coal)	27.12	3.19	2.30
CWC UU (Rejects)	7.63	43.08	12.60
Linatex Overflow	1.37	6.05	2.15
Linatex Underflow	10.32	4.25	2.50
Derrick Screen Underflow	2.72	12.53	3.97

4) Froth Flotation

	% Solids	% Ash+	% Sulphur+
Feed	1.62	9.01	3.12
Product from Cell 1	20.62	3.30	2.05
Product from Cell 2	14.20	4.65	2.32
Tailings	0.16	35.90	5.01

5) Dewatering Circuit

	% Solids	% Ash+	% Sulphur+
Thickener Feed	0.64	24.05	3.45
Thickener Overflow	0.01	NA	NA
Thickener Underflow	3.21	29.24	5.37
Clean Coal Centrifuge Effluent	7.60	4.55	2.12
Reject Centrifuge Effluent	1.57	34.59	3.21

6) Timed Samples

	% Solids	% Ash+	% Sulphur+	Mass+ Flowrate (kg/min)
Linatex Overflow	1.52	6.04	2.15	7.03
CWC OU	26.78	3.43	2.37	5.24
CWC UU	6.57	42.51	12.19	0.32

+ dry basis
* Calculated from: S.E.(db) = 35.33 - 0.43 * %Ash(db).

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TABLE 8
MATERIAL TESTED: DONKIN-MORIEN
WASH TEST: 8
DATE: Oct 15,1985

1) Feed and Products

	% Moisture	% Ash+	% Sulphur+	Specific Energy* (MJ/kg)	Total Mass+ (t)
Feed	3.67	6.59	3.44	32.50	4.18
Clean Coal	13.15	1.98	1.77	34.48	1.92
Coarse Rejects	34.11	8.15	3.00	31.83	2.11
Fine Rejects	17.84	24.14	6.65	24.95	0.15

2) Coarse Cleaning (Dense Medium Cyclone)

	% Solids	% Ash+	% Sulphur+
Deslime Screen Overflow	65.85	6.12	3.00
Clean Coal	63.28	1.06	1.52
Rejects	66.38	8.15	3.64

3) Compound Water Only Cyclone Circuit

	% Solids	% Ash+	% Sulphur+
CWC OU (Clean Coal)	34.01	3.43	2.26
CWC UU (Rejects)	5.91	47.83	13.09

+ dry basis

* Calculated from: S.E.(db)=35.33-0.43*% Ash(db)

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TABLE 9
MATERIAL TESTED: DONKIN-MORIEN
WASH TEST: 9
DATE: October 18,1985

1) Feed and Products

	% Moisture	% Ash+	% Sulphur+	Specific Energy* (MJ/kg)	Total Mass+ (t)
Feed	3.42	5.35	3.19	33.03	5.61
Clean Coal	7.37	1.85	1.74	34.54	2.81
Coarse Rejects	32.91	13.68	5.46	29.45	2.55
Fine Rejects	17.35	24.14	7.22	24.95	0.25

2) Coarse Cleaning (Dense Medium Cyclone)

	% Solids	% Ash+	% Sulphur+
Deslime Screen Overflow	69.80	5.37	3.24
Clean Coal	64.97	1.31	1.60
Clean Coal (Rinsed)	NA	1.16	1.57
Rejects	67.09	13.68	5.46

3) Compound Water Only Cyclone Circuit

	% Solids	% Ash+	% Sulphur+
Deslime Screen Underflow	3.52	6.41	2.65
CWC OU (Clean Coal)	27.37	3.10	2.23
CWC UU (Rejects)	5.66	44.66	12.19
Linatex Overflow	1.45	7.29	2.45
Linatex Underflow	12.33	4.29	2.49
Derrick Screen Underflow	3.20	11.88	3.88

4) Froth Flotation

	% Solids	% Ash+	% Sulphur+
Feed	1.73	9.12	3.11
Product from Cell 1	21.37	3.78	2.29
Product from Cell 2	11.96	4.71	2.43
Tailings	0.34	21.83	3.82

5) Dewatering Circuit

	% Solids	% Ash+	% Sulphur+
Thickener Feed	0.63	18.56	3.50
Thickener Overflow	0.04	28.97	3.88
Thickener Underflow	2.56	20.21	3.55
Clean Coal Centrifuge Effluent	8.10	4.44	2.21
Reject Centrifuge Effluent	1.18	24.42	3.50

6) Timed Samples

	% Solids	% Ash+	% Sulphur+	Mass+ Flowrate (kg/min)
Linatex Overflow	1.93	8.25	2.63	7.70
CWC OU	31.34	3.65	2.37	6.98
CWC UU	9.01	50.16	13.92	0.64

+dry basis

Calculated from: S.E (db)=35.33-0.43%Ash(db)

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DONKIN-MORIEN COAL - WASH TESTS AND WASHABILITY RESULTS

APPENDIX 4

RESULTS FROM FLOAT-SINK ANALYSIS OF THE FEED AND PRODUCTS FROM SELECTED TESTS

Table 1	BATAC JIG Donkin-Morien Coal Wash Test #2
Table 2	DENSE MEDIUM CYCLONE Donkin-Morien Test #7
Table 3	COMPOUND WATER CYCLONE Donkin-Morien Coal Wash Test #7
Table 4	DENSE MEDIUM CYCLONE Donkin-Morien Test #9

APPENDIX 4
TABLE 1

RESULTS OF THE FLOAT/SINK ANALYSIS OF THE
FEED AND PRODUCTS OF THE BATAC JIG
DONKIN-MORIEN TEST #2

Specific Gravity Fraction	Feed (+0.6 mm)	Clean Coal (+0.6 mm)	Rejects (+0.6 mm)
1.275 Floats	58.5	66.14	1.00
1.275x1.30	18.70	17.24	1.37
1.30x1.35	7.45	8.41	1.99
1.35x1.40	4.04	3.36	3.49
1.40x1.45	1.71	1.77	4.25
1.45x1.50	1.16	1.03	3.80
1.50x1.60	1.49	0.89	4.90
1.60x1.80	1.48	0.69	9.47
1.80x2.00	1.00	0.28	7.38
2.00x2.17	0.29	0.07	14.62
2.17 Sinks	4.19	0.11	47.74
% Ash	5.60	2.98	44.10
% Sulphur	3.33	2.40	12.78

All figures are on a dry basis.

APPENDIX 4
TABLE 2

RESULTS OF THE FLOAT/SINK ANALYSIS OF THE
FEED AND PRODUCTS OF THE DENSE MEDIUM CYCLONE
DONKIN-MORIEN TEST #7

Specific Gravity Fraction	Feed (+0.6 mm)	Clean Coal (+0.6 mm)	Rejects (+0.6 mm)
1.275 Floats	56.70	73.54	10.25
1.275x1.30	21.40	20.38	12.63
1.30x1.35	8.22	5.13	14.98
1.35x1.40	3.94	0.64	13.71
1.40x1.45	2.18	0.16	8.94
1.45x1.50	0.84	0.08	4.70
1.50x1.60	1.25	0.04	5.72
1.60x1.80	1.33	0.03	6.39
1.80x2.00	0.76	-	4.05
2.00x2.17	0.25	-	1.41
2.17 Sinks	3.11	-	17.22
% Ash	5.47	1.79	20.23
% Sulphur	2.91	1.91	8.37

All figures are on a dry basis.

APPENDIX 4
TABLE 3

RESULTS OF THE FLOAT/SINK ANALYSIS OF THE
FEED AND PRODUCTS OF THE COMPOUND WATER CYCLONE CIRCUIT
DONKIN-MORIEN TEST #7

Specific Gravity Fraction	Feed (0.6x0.15 mm)	Clean Coal (0.6x0.15 mm)	Rejects (0.6x0.15 mm)
1.275 Floats	46.20	66.22	6.13
1.275x1.30	35.42	15.91	5.37
1.30x1.35	7.79	9.74	2.54
1.35x1.40	3.22	2.87	3.61
1.40x1.45	1.64	1.80	3.85
1.45x1.50	1.32	1.08	1.92
1.50x1.60	1.07	0.90	3.45
1.60x1.80	1.21	0.89	8.53
1.80x2.00	0.32	0.33	8.34
2.00x2.17	0.21	0.25	5.62
2.17 Sinks	1.61	-	50.65
% Ash	4.02	2.48	45.16
% Sulphur	2.50	2.05	12.28

All figures are on a dry basis.

APPENDIX 4
TABLE 4

RESULTS OF THE FLOAT/SINK ANALYSIS OF THE
FEED AND PRODUCTS OF THE DENSE MEDIUM CYCLONE
DONKIN-MORIEN TEST #9

Specific Gravity Fraction	Feed (+0.6 mm)	Clean Coal (+0.6 mm)	Rejects (+0.6 mm)
1.275 Floats	62.86	84.03	36.23
1.275x1.30	18.64	13.49	22.79
1.30x1.35	7.28	1.95	12.65
1.35x1.40	3.81	0.40	7.26
1.40x1.45	1.67	0.07	2.38
1.45x1.50	0.90	0.03	2.18
1.50x1.60	1.28	0.02	3.98
1.60x1.80	1.08	0.01	2.44
1.80x2.00	0.45	-	1.66
2.00x2.17	0.13	-	0.64
2.17 Sinks	1.89	-	7.79
% Ash	5.05	1.16	11.09
% Sulphur	3.12	1.57	4.64

All figures are on a dry basis.

APPENDIX C

COAL WASHABILITY AND ASH-kJ/kg RELATIONSHIP

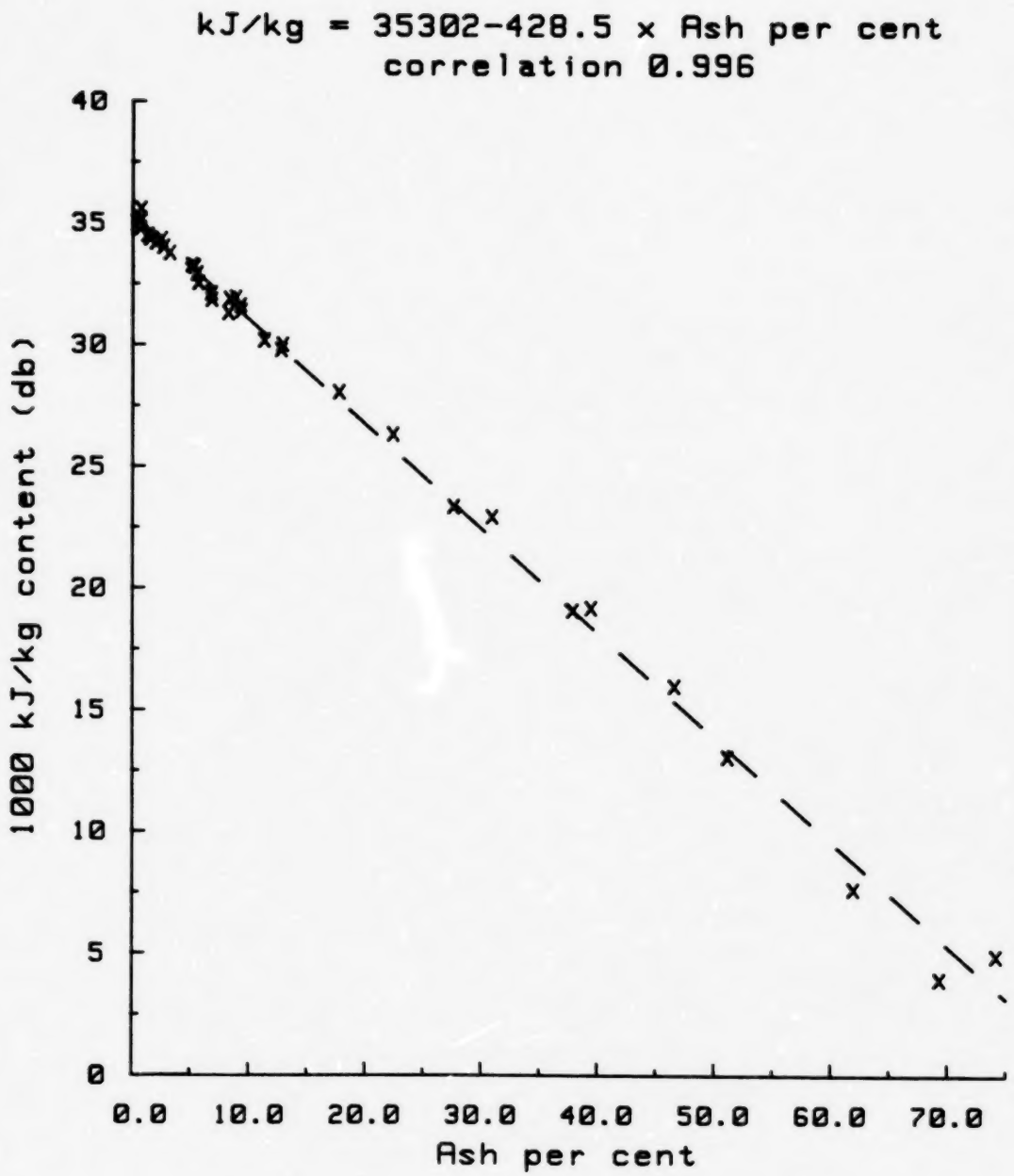

Figure C-1 - Percent ash v.s. heat value - Donkin-Morien.

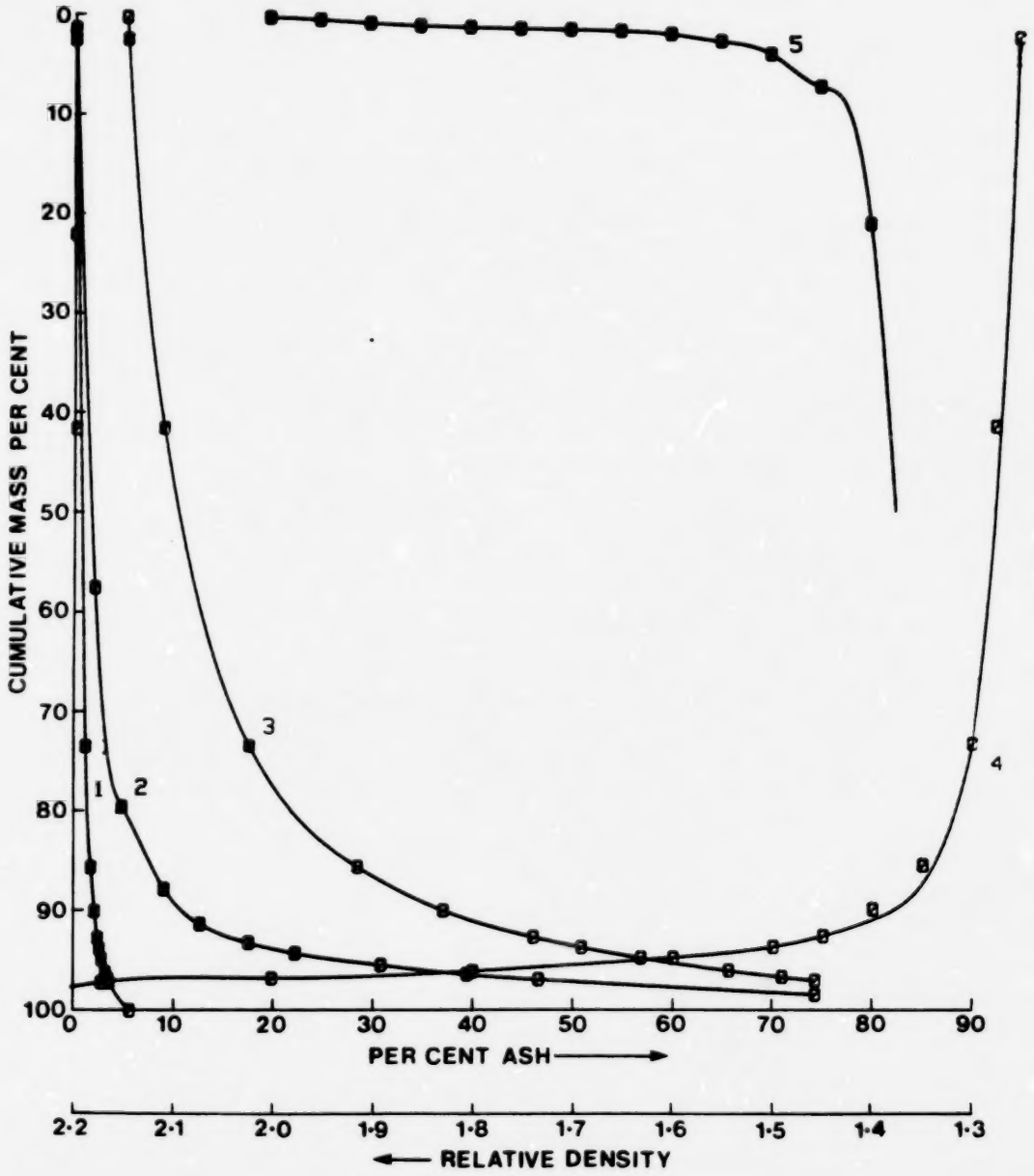

Figure C-2 - Washability curves of wet attrited Donkin-Morien coal (+0.6mm).

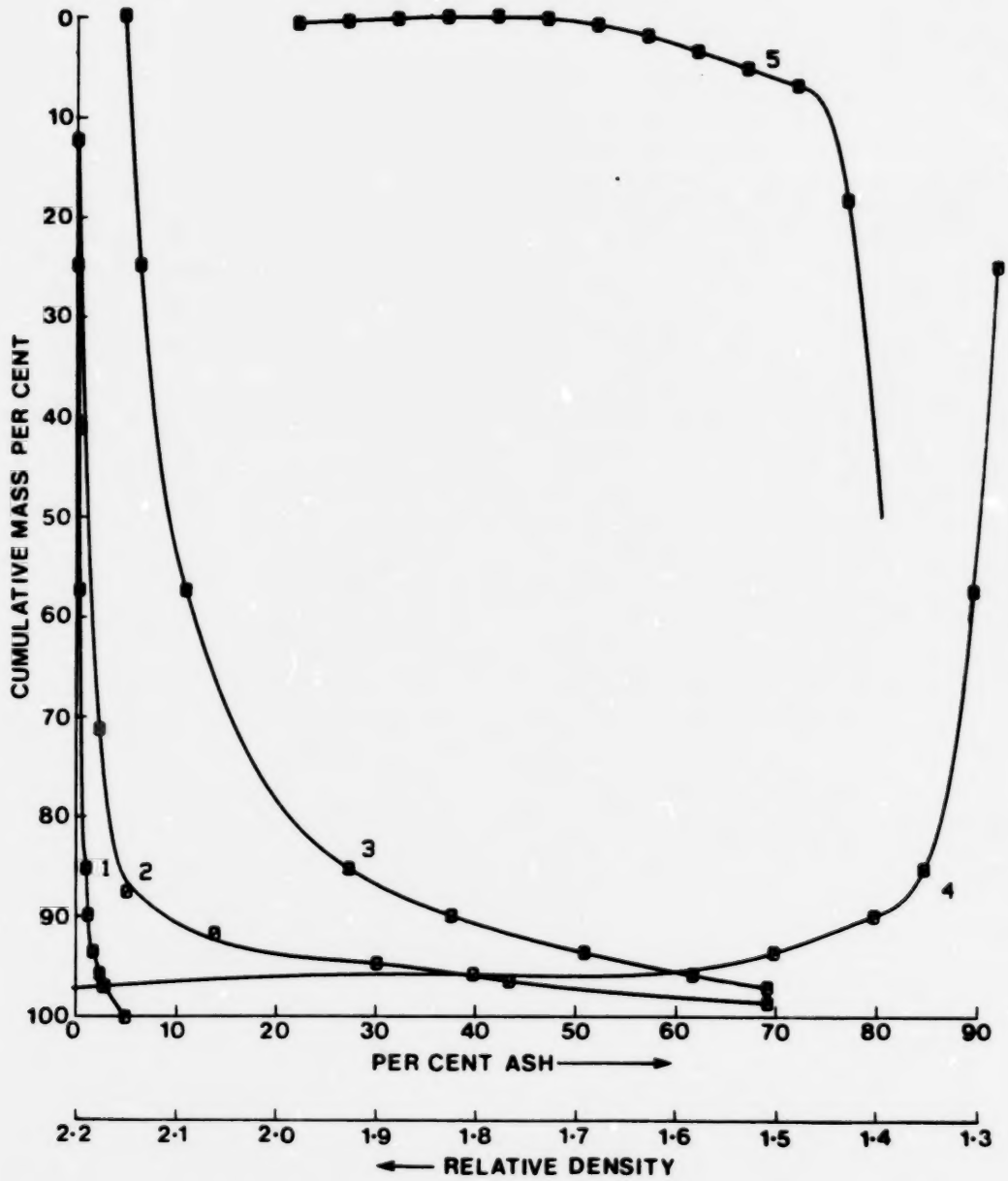

Figure C-3 - Washability curves of wet attrited Donkin-Morien coal (0.6 X 0.15mm).

APPENDIX D

BENCH SCALE FLOTATION RESULTS

Table D-1 - Donkin Morien minus 0.6 mm flotation tests (standard conditions)

Flotation Unit	Denver Bench Scale
Cell capacity	2 l(nominal)
Mass of water initially	2000 g
Mass of coal	222.2 g
Per cent solids	10% by mass
Impeller speed	1000 rpm
Air Flow	free
Conditioning time after wetting of coal:	
Flocculant reagent	120 seconds
Flotation reagents	180 seconds

Table D-2 - Donkin Morien minus 0.6 mm flotation tests using MIBC

		Elemental Data			Cumulative Data			Efficiencies	
Dose kg/tonne	Time (Sec)	Mass%	Ash%	S%	Mass%	Ash%	S%	Ash	Sulphur
2.30	0-30	71.07	4.37	2.60	71.07	4.37	2.60	407	145
	30-60	13.48	7.62	3.34	84.55	4.89	2.72	696	219
	60-120	5.43	15.26	5.07	89.98	5.51	2.86	878	255
	120-180	2.98	22.75	5.56	92.96	6.07	2.95	1025	290
	Tailings	7.04	66.92	9.20	100.00	10.35	3.39	----	---
0.38	0-30	84.68	5.01	2.52	84.86	5.01	2.52	493	248
	30-60	7.35	12.12	4.51	92.21	5.58	2.68	745	345
	60-120	1.94	26.70	7.60	94.15	6.01	2.78	802	367
	120-180	1.05	37.29	8.26	95.20	6.36	2.84	812	382
	Tailings	4.80	54.22	11.40	100.00	8.65	3.25	----	---
0.26	0-30	82.97	4.45	2.46	82.97	4.45	2.46	524	265
	30-60	7.40	11.20	4.43	90.37	5.00	2.62	742	362
	60-120	2.79	21.11	6.54	93.16	5.49	2.74	835	413
	120-180	1.11	34.42	7.14	94.27	5.83	2.79	842	443
	Tailings	5.73	52.05	13.10	100.00	8.47	3.38	---	---
0.13	0.30	74.55	4.02	2.29	74.55	4.02	2.29	409	199
	30.60	11.81	8.73	3.62	86.36	4.66	2.47	622	289
	60-120	3.54	16.73	5.25	89.90	5.14	2.58	691	325
	120-180	1.14	28.35	6.74	91.04	5.43	2.63	686	334
	Tailings	8.96	40.92	9.66	100.00	8.61	3.26	---	---
0.04	0-30	24.21	5.02	2.47	24.21	5.01	2.47	48	37
	30-60	11.90	5.20	2.35	36.11	5.08	2.43	77	59
	60-120	8.71	5.85	2.63	44.82	5.23	2.47	99	77
	120-180	3.74	8.03	3.11	48.56	5.44	2.52	106	83
	Tailings	51.44	11.84	4.30	100.00	8.73	3.43	---	--

Table D-3 - Donkin Morien minus 0.6 mm flotation tests using 5:1 Kerosene: MIBC

		Elemental Data			Cumulative Data			Efficiencies	
Dose * kg/tonne	Time (Sec)	Mass%	Ash%	S%	Mass%	Ash%	S%	Ash	Sulphur
0.38	0-30	77.44	5.02	2.67	77.44	5.02	2.67	355	157
	30-60	11.37	9.64	3.57	88.81	5.61	2.79	579	233
	60-120	2.43	15.33	4.39	91.24	5.87	2.83	660	262
	120-180	1.62	24.73	5.10	92.86	6.20	2.87	696	285
	Tailings	7.14	46.48	8.79	100.00	9.08	3.29	----	---
0.25	0-30	73.28	5.60	2.83	73.28	5.60	2.83	219	123
	30-60	15.72	8.33	3.36	89.00	6.08	2.92	421	205
	60-120	3.58	14.15	4.07	92.58	6.39	2.97	519	251
	120-180	1.50	17.71	4.61	94.08	6.57	2.99	579	280
	Tailings	5.92	40.43	8.91	100.00	8.58	3.34	----	---
0.13	0-30	71.12	4.80	2.54	71.12	4.80	2.54	265	145
	30-60	11.89	8.30	3.23	83.01	5.30	2.64	385	206
	60-120	7.75	14.30	4.20	90.76	6.07	2.77	496	279
	120-180	0.92	23.49	5.56	91.68	6.24	2.80	503	290
	Tailings	8.32	34.24	8.86	100.00	8.57	3.30	---	---
0.06	0.30	75.74	4.97	2.60	75.74	4.97	2.60	350	179
	30.60	5.66	9.18	3.33	81.40	5.26	2.65	420	215
	60-120	3.72	17.86	4.48	85.12	5.81	2.73	431	238
	120-180	1.52	21.30	5.40	86.64	6.08	2.78	433	246
	Tailings	13.36	30.38	7.88	100.00	9.33	3.46	---	---
0.03	0-30	38.67	5.84	2.54	38.67	5.84	2.54	69	60
	30-60	8.01	7.12	2.80	46.68	6.06	2.58	84	74
	60-120	12.11	7.54	2.86	58.79	6.36	2.64	110	100
	120-180	6.15	8.86	3.17	64.94	6.60	2.69	122	113
	Tailings	35.06	12.44	4.70	100.00	8.65	3.40	---	--

* Frother

Table D-4- Donkin Morien minus 0.6 mm flotation tests using 5:1 Kerosene: M210

		Elemental Data			Cumulative Data			Efficiencies	
Dose * kg/tonne	Time (Sec)	Mass%	Ash%	S%	Mass%	Ash%	S%	Ash	Sulphur
0.38	0-30	65.05	5.04	2.67	65.05	5.04	2.67	210	113
	30-60	13.78	6.24	2.97	78.83	5.25	2.72	342	167
	60-120	4.29	11.87	3.79	83.12	5.59	2.78	380	187
	120-180	2.85	16.08	3.94	85.97	5.94	2.82	398	205
	Tailings	14.03	27.51	6.72	100.00	8.97	3.36	----	---
0.25	0-30	69.30	6.57	2.56	69.30	6.57	2.56	153	124
	30-60	4.63	7.53	3.04	73.93	6.63	2.59	175	138
	60-120	9.65	10.35	2.94	83.58	7.06	2.63	224	189
	120-180	2.90	11.09	3.25	86.48	7.19	2.65	247	213
	Tailings	13.52	20.58	6.54	100.00	9.00	3.18	----	---
0.13	0-30	52.99	5.13	2.56	52.99	5.13	2.56	137	95
	30-60	8.44	6.95	3.04	61.43	5.38	2.63	168	116
	60-120	10.58	7.99	2.94	72.01	5.76	2.67	215	154
	120-180	7.05	9.29	3.25	79.06	6.08	2.72	259	190
	Tailings	20.94	19.89	6.54	100.00	8.97	3.52	---	---
0.06	0.30	42.77	6.21	2.67	42.77	6.21	2.67	77	62
	30.60	11.02	6.70	2.75	53.79	6.31	2.69	104	83
	60-120	10.27	7.23	2.72	64.06	6.46	2.69	135	109
	120-180	4.64	8.17	3.04	68.70	6.57	2.72	150	121
	Tailings	13.30	14.37	4.80	100.00	9.01	3.37	---	---
0.03	0-30	33.11	4.07	2.33	33.11	4.07	2.23	95	58
	30-60	13.01	5.98	2.38	46.12	4.61	2.27	131	87
	60-120	11.50	9.15	3.34	57.62	5.52	2.49	148	106
	120-180	6.44	10.78	3.23	64.06	6.04	2.56	156	120
	Tailings	35.94	14.74	4.80	100.00	9.17	3.37	---	--

* Frother

Table D-5- Donkin Morien minus 0.6 mm flotation tests using 5:1 Kerosene: (M150 + M210)

		Elemental Data			Cumulative Data			Efficiencies	
Dose * kg/tonne	Time (Sec)	Mass%	Ash%	S%	Mass%	Ash%	S%	Ash	Sulphur
0.38	0-30	85.87	6.14	2.91	85.87	6.14	2.91	312	158
	30-60	9.02	10.17	4.27	94.89	6.52	3.04	636	228
	60-120	2.11	17.45	5.25	97.00	6.76	3.09	892	275
	120-180	0.33	33.03	6.52	97.33	6.85	3.10	935	284
	Tailings	2.67	65.81	9.04	100.00	8.42	3.26	----	---
0.26	0-30	87.60	5.55	2.85	87.60	5.55	2.85	417	206
	30-60	7.16	13.06	5.58	94.76	6.12	3.06	692	256
	60-120	1.87	15.61	4.87	96.63	6.30	3.09	932	316
	120-180	0.46	28.53	5.72	97.09	6.41	3.10	998	338
	Tailings	2.91	65.86	10.82	100.00	8.14	3.33	----	---
0.13	0-30	89.11	5.59	3.16	89.11	5.50	3.16	529	197
	30-60	4.95	12.40	4.57	94.06	5.86	3.23	795	261
	60-120	1.48	25.47	6.08	95.54	6.17	3.28	891	289
	120-180	0.32	47.47	8.72	95.86	6.30	3.30	886	291
	Tailings	4.14	58.29	10.02	100.00	8.46	3.57	---	---
0.06	0.30	75.07	4.49	2.58	75.07	4.49	2.58	350	163
	30.60	9.34	7.16	3.23	84.41	4.79	2.65	515	224
	60-120	4.07	9.55	3.74	88.48	5.00	2.70	639	268
	120-180	2.45	17.71	4.54	90.93	5.35	2.75	700	303
	Tailings	9.07	41.14	9.18	100.00	8.59	3.33	---	---
0.03	0-30	29.98	3.50	2.14	29.98	3.59	2.14	99	54
	30-60	11.45	4.48	2.27	41.43	3.77	2.18	143	80
	60-120	9.89	6.99	2.74	51.32	4.39	2.28	166	100
	120-180	6.34	9.22	3.05	57.66	4.92	2.37	175	114
	Tailings	42.34	14.96	4.68	100.00	9.17	3.35	---	--

* Frother

Table D-6- Donkin Morien minus 0.6 mm flotation tests using Kerosene:

		Elemental Data			Cumulative Data			Efficiencies	
Dose * kg/tonne	Time (Sec)	Mass%	Ash%	S%	Mass%	Ash%	S%	Ash	Sulphur
0.38	0-30	37.80	3.76	2.18	37.80	3.76	2.18	129	73
	30-60	9.53	5.30	2.54	47.33	4.07	2.25	166	94
	60-120	4.26	8.05	3.22	51.59	4.40	2.33	173	102
	120-180	8.72	9.49	2.94	60.31	5.13	2.42	187	124
	Tailings	39.69	15.94	4.97	100.00	9.42	3.43	----	---

* Frother

Table D-7- Donkin Morien minus 0.6 mm flotation tests using 0.13 kg/tonne 5:1 K:MIBC after flocculating with E10

		Elemental Data			Cumulative Data			Efficiencies	
Dose kg/tonne	Time (Sec)	Mass%	Ash%	S%	Mass%	Ash%	S%	Ash	Sulphur
0	0-30	71.12	4.80	2.54	71.12	4.80	2.54	265	145
	30-60	11.89	8.30	3.23	83.01	5.30	2.64	385	206
	60-120	7.75	14.30	4.20	90.76	6.07	2.77	496	279
	120-180	0.92	23.49	5.56	91.68	6.24	2.80	503	290
	Tailings	8.32	34.24	8.86	100.00	8.57	3.30	----	---
50	0-30	88.73	6.13	2.94	88.73	6.13	2.94	401	202
	30-60	4.59	9.69	3.50	93.32	6.31	2.97	594	279
	60-120	1.19	14.45	4.01	94.51	6.41	2.98	674	315
	120-180	0.43	19.45	4.54	94.94	6.47	2.99	704	330
	Tailings	5.06	47.93	10.40	100.00	8.56	3.36	----	---
100	0-30	85.25	5.99	3.05	85.25	5.99	3.05	318	161
	30-60	6.04	8.49	3.35	91.29	6.16	3.07	474	222
	60-120	1.47	14.31	3.78	92.67	6.28	3.08	525	247
	120-180	0.51	17.07	4.09	93.27	6.34	3.09	543	257
	Tailings	6.73	36.95	8.51	100.00	8.40	3.45	---	---
300	0.30	18.95	11.34	3.32	18.95	11.34	3.32	14	20
	30.60	5.39	8.91	2.95	24.34	10.80	3.24	19	26
	60-120	7.38	6.73	2.63	31.72	9.85	3.10	28	37
	120-180	3.83	5.86	2.63	35.55	9.42	3.05	34	42
	Tailings	64.45	9.02	3.64	100.00	9.16	3.43	---	---
500	0-30	20.35	10.88	3.45	20.35	10.88	3.45	15	22
	30-60	5.22	9.96	3.15	25.57	10.69	3.39	19	28
	60-120	4.98	7.37	2.85	30.55	10.15	3.30	24	35
	120-180	3.19	5.94	2.59	33.74	9.75	3.23	28	40
	Tailings	66.26	8.19	3.82	100.00	8.72	3.62	---	--